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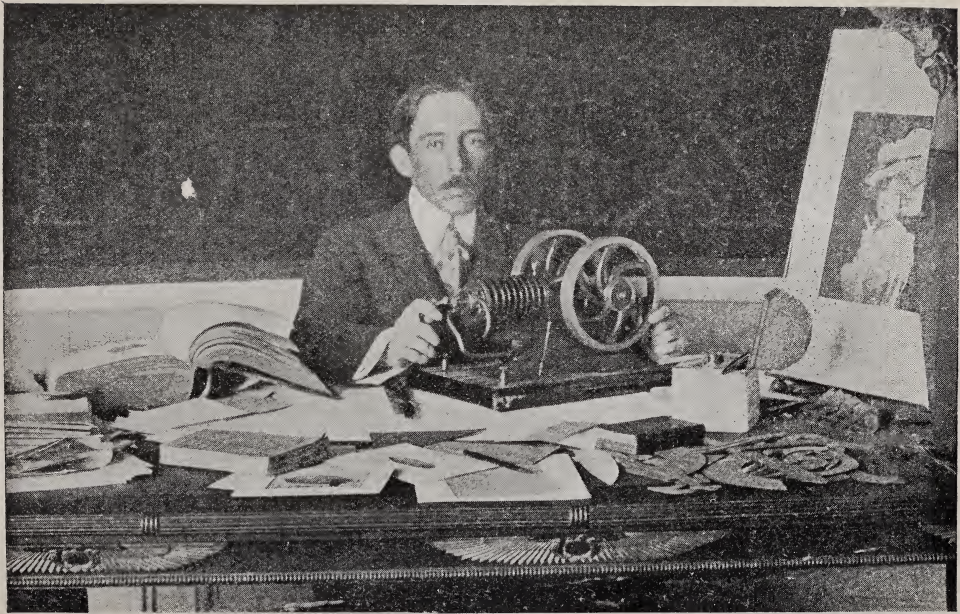

M. SANTOS DUMONT IN HIS STUDY.

Frontispiece.

Flying Machines:

PAST, PRESENT AND FUTURE.

A Popular Account of Flying Machines, Dirigible Balloons and Aeroplanes.

BY

ALFRED W. MARSHALL, M.I.Mech.E.

AND

HENRY GREENLY.

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CONTENTS.

PREFACE.

WHILST the matter contained in this book is intended as a popular exposition of the subject it includes information which may assist the reader with serious intention of making an attempt to produce a flying machine, or airship. A great deal of sound experimental work has been done by many investigators forming a basis upon which future plans can be calculated. An account of some of this work is given in these pages, and though necessarily incomplete will give an idea of what has been accomplished and that which may be possible. Further sources of information are indicated so that the reader may extend his search if he desires to do so. It has not been considered advisable to include mathematical formulæ or to attempt calculations for designs as these are beyond the scope of the book. Flying machines of the past are taken to be the models and machines used by experimenters of intelligence and scientific ability. No account is taken of the grotesque or mythical aerial machines which, though placed on record in various publications, have probably only existed in imagination or upon paper. Flying machines of the present are taken to be those which have been constructed and tried within the last two or three years. As regards flying machines of the future, the reader is left to picture these for himself with the assistance of Chapter V.

In mentioning certain experimenters it is recognised that others have done excellent work also. Readers who will consult the pages of *Engineering*, the *Encyclopædia Britannica* (subject "Æronautics"), "Progress in Flying Machines" by Chanute, "Navigation Arienne" by Lecornu, "Ariation depuis, 1891," by Ferber, etc., will find mention of various experimenters and their work with extended information upon aerial navigation and machines. These sources have been consulted in the preparation of this volume, and to them the authors extend their grateful acknowledgments. They also wish to pay a tribute of respect to the brave pioneers who have sacrificed their lives in endeavouring to advance the art of mechanical flight.

CHAPTER I.

Introduction.

At the present day the fascinating problem how to make a successful flying machine is attracting attention in all civilised countries. A valuable prize has actually been won in France by a navigable airship which has been propelled over a given course, starting from a definite locality and returning to the same place in a limited period of time. The custom of regarding any attempt to navigate the air as an indication of madness on the part of the experimenter has passed away, and is now replaced by a feeling of anxiety that one's own country shall not be forestalled in the art of aviation. Sir Hiram Maxim, the well-known engineer and inventor, has stated years ago that one half of the leading scientists in the United States are of the opinion that mechanical flight is possible.

The subject is attractive because of the large amount of chance or luck which exists in respect to it. There is no industry manufacturing airships as a commercial article; no one has so far made a flying ship or apparatus which can not only ascend into the air with a load, but can be driven in any desired direction under normal conditions of wind and weather. There is so much possibility that an experimenter may by accident discover the true direction in which to proceed. Work on a large scale can only be done at very heavy expense, but probably the majority of experimenters in this field would in any case commence by trials with model machines. Really useful experience can be gained at comparatively trifling expense in this way, and a would-be conqueror of the air can fairly assume that without actual experiment of some sort no reliance can be placed upon his designs, however pretty they may look on paper. Designs of airships have ranged themselves into three classes. There have been those who have taken the principle of buoyancy as their basis of construction; they are those who look for the solution of the problem by an apparatus which is "lighter than air." The examples are balloons. Others hold a contrary opinion, directing their efforts to the perfection of machines which are "heavier than air," disregarding entirely the principle of buoyancy, and contend that the machine must raise itself as well as have the power to move in a horizontal direction. The examples are kites, the term aeroplane having been introduced to define this type of construction, and machines in which some form of screw propeller or vibrating plane is relied upon to produce the lifting effort. The third division of designers appears to be those who have adopted the principle of buoyancy as affording a temporary expedient which would serve until further disco-

PLATE I.—Dr. Barton's Airship in Flight.

(The Ascent of July, 1905.)

Facing page 8.

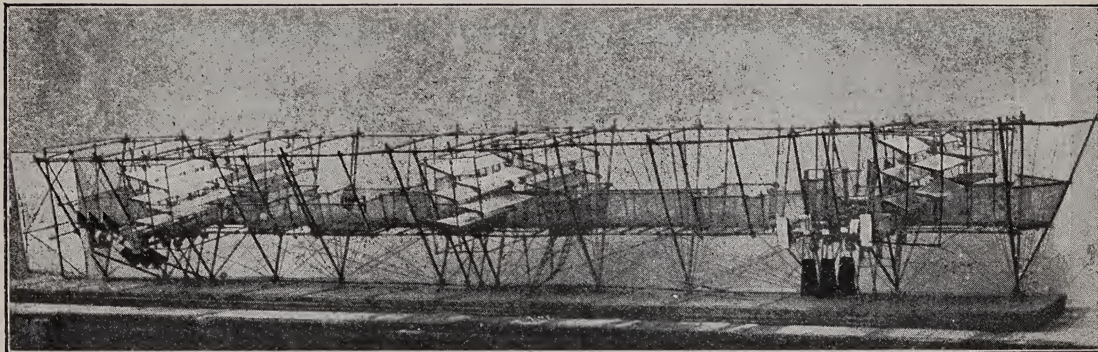

PLATE II.—The Model of Dr Barton's Airship.

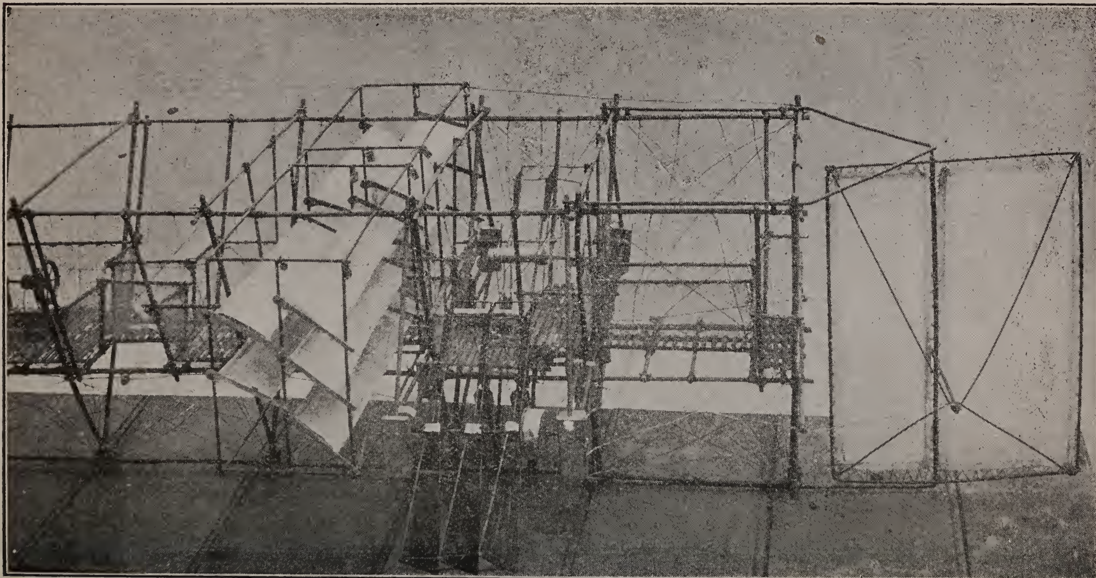

PLATE III.—The Model of Dr. Barton's Airship: View of Stern showing Propellers, Aeroplanes, and Rudder.

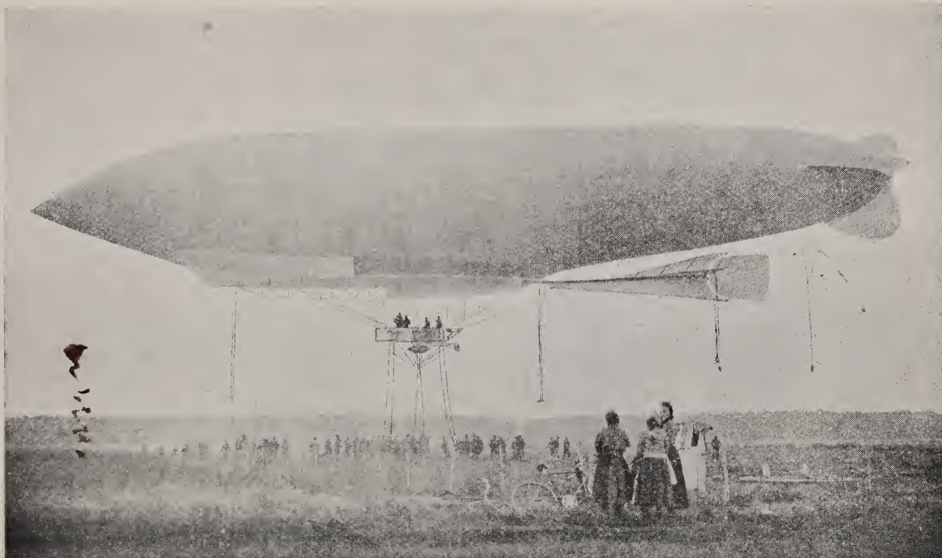

PLATE IV.—Messrs. Lebaudy's Military Airship "La Patrie" in Flight.

very would render practicable the use of machines "heavier than air." The earliest designers seem to have adopted the idea of machines heavier than air, but probably no reliable information exists as to what was actually accomplished. Designs of more or less fantastic shape have been proposed, but only appear upon paper; any real attempts have all occurred during comparatively recent years. Some inventors were no doubt men of capability, and deserved to have met with some success, but they were not sufficiently cautious or methodical, and in making ambitious trial flights with their machines met with fatal disaster. A great deal of very useful and reliable work has, however, been accomplished by men of scientific ability, and placed on record; the novice can, therefore, make himself acquainted with the results of the experiments and utilise them as a starting point for his own work, whether his faith is in a ship which is lighter or heavier than air. Such data will give him an idea of the size and proportion of parts to accomplish a given result. In considering the problem of aerial navigation it is necessary to realise that the atmosphere is a decidedly real and tangible thing. Because air is invisible the mind does not easily picture its existence, hence the novelty of imagining it to be of service in sustaining and transporting material objects. Aeronauts have, however, recorded their experience of descents in which the air appeared to be a substance like jelly. Air has a definite weight, 100 cubic inches weighing 31 grains ; the wind which we feel exerts a palpable pressure, and is merely air in a state of eddies and flow of currents. This wind pressure is capable of exerting an enormous amount of force, architects and engineers when designing large or tall structures require to take this fact into serious consideration. A wind which is blowing with a velocity of 10 to 15 miles per hour would exert a pressure of one-half to one pound upon every square foot of surface directly exposed to it, and yet is only a very modest breeze indeed. A storm wind blowing at about 50 miles per hour presses with more than 12 lbs. upon each square foot of surface directly exposed to it, whilst a hurricane wind exerts more than four times this pressure.

It is therefore quite reasonable to assume that a medium which is capable of producing such effects can be utilised as a means of communication and transport. To be completely successful, however, an airship must not only be able to lift itself and a load, but have the power to proceed against such winds in a horizontal direction. Buoyancy alone is not sufficient, it will enable the ship to proceed with a favourable wind astern, and to ascend and descend, but not to proceed against a wind of the most moderate force. An airship competes against other forms of travel on land and water. In each the traveller is already able to proceed in any direction, irrespective of the conditions of the weather, except in rare instances of storm and stress; even then he may be able to maintain his position until the weather moderates. If airships are to justify their existence they must be able to do this also, and to do it on a commercial basis, having regard to the particular sense in which any one may be used. The first airships to achieve any degree of success, and the only ones at the present time which are practicable as a means of aerial locomotion, are balloons. They depend entirely upon the principle of buoyancy to rise and sustain themselves and their load in the air. The principle is briefly this—if any body floats in equilibrium in a fluid the weight of the body is equal to the weight of the fluid which it displaces. If the weight of the body is less than that of the fluid displaced by it the body will rise. For example, if a sealed tin can containing air is forced below the surface of a tank of water and then released it will at once rise to the surface, because it is much lighter than the equivalent bulk of water. If the can is loaded until its weight is exactly equal to that of the equivalent bulk of water, it will remain in equilibrium below the surface. Any slight change in the weight of the can and its contents will cause it to rise or fall until a state of balance is produced due to the varying density of the water at the different depths. The weight of water displaced by the can in every instance exactly balancing the weight of the can and its contents. The density of the atmosphere varys to a very much greater extent than the density of water for a given vertical distance.

It is therefore possible to adjust the position of equilibrium within much smaller limits of movement than in the case of a body immersed in water. Water is, however, about 800 times as dense as air for any given volume, the floating body must therefore be so much larger to support a given weight in air than in water. Any apparatus used for the purpose of propulsion must also be very much larger as it cannot grip the less dense medium so well. It does not follow, however, that it need be useless or less efficient provided that the shape and proportions are suitable to the conditions of working.

A balloon is simply a device for displacing a sufficient quantity of air to balance its weight and that of the load to be lifted. The shape does not affect this part of the problem, it is merely a question of size. The less the weight of the component parts of the balloon the smaller it will need to be to lift a given load. For this reason such materials as silk, cane, and rope or thin steel wire are much used for the construction of balloons and their equipment. The substance contained in the balloon to take the place of the air displaced must be less dense than air, because the difference between its weight and that of an equivalent quantity of air is a measure of the lifting power available. The best arrangement would be a vacuum in the balloon as that would give the greatest possible difference between the weights of the cubic space in the envelope or container and the equivalent quantity of air. Such a method has actually been thought of by early designers but owing to the fact that the atmosphere exerts a pressure of approximately 15 lbs. per square in. in all directions, the envelope must be strong enough to withstand this pressure if it contains a vacuum. An envelope having sufficient strength to withstand the accumulated pressure upon such a large surface as possessed by an average balloon would weigh more than the air displaced and the balloon would not rise. If the envelope contains a gas the pressure of the air can be balanced, or more than balanced, by the expansive property of the gas, therefore the envelope can then be made of exceedingly light material. It then remains to procure a gas which is much lighter than air; such a gas is hydrogen, 100 cubic ins. of which will only weigh about 2·14 grains, or about one-fifteenth the weight of a similar quantity of air. This is the substance which will give the greatest lifting power as it is the lightest thing known. Owing to the expense of generating pure hydrogen, however, coal gas, which is hydrogen mixed with carbon, is generally used for inflating modern balloons. Being a commercial product it is comparatively cheap and gives a good lifting effort, but the very best effect is produced by pure hydrogen. The difference between the weights of the completely equipped balloon and that of the quantity of air displaced need only be about 10 lbs. in favour of ascension, such margin gives sufficient ascending power to take the balloon to a considerable height.

A certain amount of extra weight is attached to the balloon in form of paper or sand so that a reserve of lifting power is obtained. When the aeronaut desires the balloon to rise he throws away some of this weight thus increasing the buoyancy; if he desires to descend he permits some of the gas to escape by opening a valve thus decreasing the buoyancy. With this power of ascending and descending he can place the balloon at different elevations and move horizontally according to the direction of the air currents met with. This gives a certain amount of control over the direction in which the balloon will travel without the use of propelling apparatus, as air does not necessarily travel in one direction only at all degrees of elevation. If the balloon is made to rise and fall by this means there must be a limit to the time it can remain in the air. The continual releaseof gas diminishes the rese rve of lifting power until finally, when all the extra weight has been thrown away and the balloon is made to descend, it cannot be made to rise again; or the descent be checked, because the lifting power is not sufficient to sustain the load.

When the balloon ascends the atmospheric pressure diminishes, becoming less the higher the elevation attained. This permits the gas inside the balloon to expand, the effect being that as the pressure outside decreases that inside increases, and, unless a means of escape is provided, the envelope would burst with disastrous results to the occupants of the car. A loss of gas thus takes place additional to that required to regulate the buoyancy, and it is intensified by the effect of shadow and sunshine, which causes the gas to expand as it becomes heated by the sun's rays and to cool when they are obscured by cloud. Apart from the object of seeking suitable air currents at different altitudes the aeronaut who is merely voyaging from one place to another would preferably keep his balloon at a fairly constant moderate altitude. This can be done where the nature of the ground permits without sacrificing the reserve of lifting power by using what is called a guide rope, an invention of immense value in ballooning and due to a celebrated English aeronaut, Charles Green. The arrangement consists of a long heavy rope attached to the car of the balloon and allowed to hang vertically downwards so that it touches the ground. It forms a part of the extra weight but, unlike the loose sand or paper, is not thrown away. Whilst this rope is suspended away from the ground its entire weight is acting against the lifting effort of the balloon. If the buoyancy decreases the rope will touch the ground and as the balloon descends an increasing amount of its length will rest upon the ground. The balloon will obviously be relieved of the weight of this portion and therefore its buoyancy will be increased accordingly, the descent will be checked and a state of equilibrium produced. In fact as the balloon rises and falls due to variations in the buoyancy so will the guide rope rest with more or less of its weight upon the ground and act as an automatic regulator of the lifting effort.

The shape of a balloon is determined by the use to which it will be put. If it is to be used as a drifting balloon the shape will be approximately spherical, as the work which it will do is merely to float in the currents of air. But if it is to be a dirigible balloon the shape will be elongated in the direction of its horizontal axis, because the shape should be such as to offer the smallest practicable amount of resistance when proceeding against the direction of flow of an air current. The shape which gives best results in this respect is somewhat similar to that adopted for the Whitehead torpedo, and agrees with the experiments of Captain Renard, in France, who found that an elongated balloon which is larger in diameter at the forward end and smaller at the rear end, requires less power to drive it through the air than if it had ends of equally pointed shape.

The envelope of a drifting balloon only has to bear the strain of supporting the car and its load, except under abnormal circumstances. The shape, therefore, does not tend to become distorted. A dirigible balloon, however, is subjected to the pressure of the air current against which it may be moving; its envelope must therefore be able to withstand this strain as well as that due to the effort required for lifting and sustaining the car and load. This is one of the difficulties which the designer of a dirigible balloon has to deal with. If the aeronaut releases some of the gas for the purpose of descending he is depriving the envelope of its internal support, and may come to disaster by reason of the distortion of the shape of his balloon. According to M. Santos Dumont, the successful dirigible balloon must be able to descend without losing gas and ascend without sacrificing ballast; in fact, you must not interfere with the reserve of lifting power.

This can be effected by an ingenious device which was suggested at the end of the eighteenth century by General Mensuir and used by Dupuy de Lôme in his balloon, as well as by Santos Dumont himself. It consists of a small balloon or pocket fixed inside the main envelope, and filled with air, which is kept at pressure by means of a fan. The gas can thus expand without unduly straining the envelope by pressing against the pocket which collapses, losing more or less of the contained air, and making more space for the gas inside the main envelope. If the gas contracts the pump inflates the pocket again with air, so that the reduction in bulk of the gas is compensated. Escape valves are provided for the air, a regular stream flowing through the pocket under normal conditions. The balloon is elevated and descends by the action of its propeller, the envelope being tilted to point upwards or downwards by an alteration of balance. M. Santos Dumont uses his guide rope for this purpose, shifting its position so that the weight pulls at front, rear, or centre, according to the angle at which he desires the balloon to go.

Attempts have been made to direct airships by means of sails, but without much success. There are two other methods which have been used, namely, by screw propellers and by vibrating planes or wings. Neither of these has yet been proved to be the superior one. Mr. Laurence Hargrave, in Australia, has made models propelled by both methods, each flying well. Sir Hiram Maxim and Mr. Horatio Phillips in England, Messrs. Santos Dumont, Tissandier, Captains Renard and Krebs in France, and others have done well with screw propellers driven by steam, petrol, electric, and compressed-air engines, though the two first-named inventors did not permit their machines to have free flight.

The problem of aerial navigation by machines heavier than air resolves itself into two main components, viz., power of sustaining a load in air and power of maintaining a proper balance. If these can be achieved, the factor of propulsion is comparatively easy to deal with. One of the most able of scientific experimenters in this art, Otto Lilienthal of Berlin, who commenced his trials of flight at 13 years of age, and continued them for 25 years, eliminated the question of motive power, and confined himself entirely with the problem of balance. He decided that soaring birds ascend by skilful use of the pressure produced by currents of air, and that no external source of power is needed to imitate them, all the apparatus required being sustaining surfaces correctly designed and constructed, with of course an acquired art in using them properly. His investigations were published in 1889 as a book, called "Der Vogelflug als Grundlage der Fliegekunst" ("Bird Flight as the Basis of the Flying Art"), and his opinion was that birds fly by dexterity alone; there is no mysterious upward force or kind of reversed gravity.

Making some experiments whilst suspended from a support by means of a rope, he actually succeeded in raising himself about 30 ft. from the ground by means of wings, which he vibrated by his own power, his weight and that of the machine being, however, partly counterbalanced. The majority of his experiments consisted in gliding flights taken from the top of a hill having a moderate slope. These trials were taken so often that he regarded them as a sport, in which his mechanic assistant also participated. The apparatus consisted of fixed aeroplanes, to which he attached himself, always facing the wind. Notwithstanding the proficiency and experience thus gained, Lilienthal met his death whilst engaging in the attempt to make a flight of greatest possible length in the capacity of his apparatus. A sudden gust of wind appears to have been too heavy for him to adjust his equilibrium to meet it, and the soundness of his opinions upon this point were unluckily proved by the aeroplanes being thrown backwards from their proper angle. The apparatus thus deprived of the supporting effect of the wind fell rapidly to the ground, and the accident proved fatal to the enthusiastic and able experimenter.

Professor Langley, another very clever worker at this problem in the United States, constructed a model machine which would travel against the wind and yet keep at an average horizontal level. He considers that a machine can be designed and made which would carry out this principle of soaring bird flight by utilising the fluctuations of wind velocity, which, according to his ideas, occurred between very much smaller intervals of time than generally supposed. To satisfy himself that this was so, he made some accurate experiments by using a very sensitive anemometer, which recorded as well as indicated the velocity and fluctuations of wind during short intervals of time. An account of these experiments is given in the Proceedings of the Smithsonian Institute, July, 1904, entitled "The Internal Work of the Wind," showing graphic curves of wind velocities plotted against intervals of time. They show that changes take place with great rapidity and to an extraordinary extent. Existing records as taken by an ordinary anemometer, registering at long intervals of time, showed wind velocity variation only from 20 to 27 miles per hour; but the true fluctuations as recorded by the special anemometer were enormously more than this, and occurred with great suddenness. As an example, the velocity would vary within the space of one minute from about 30 miles per hour to zero, then to 14 miles per hour, and regain its former velocity within the space of two minutes, including some intermediate fluctuations of 12 miles per hour or so occurring in between. Some of these curves are to be found in *Engineering* for July 13th, 1884, page 51.

A pioneer experimenter in this idea of the principle of bird flight was Le Bris, who made some actual flights in France. He was a sea captain, and seems to have had a very good grasp of the problem. From observations on soaring birds made by him during his voyages, he came to the conclusion that when the current of air strikes the forward edge of the bird's wing an aspirating action is produced, by which the bird is actually drawn into the wind without any effort on its own part. He shot an albatross, and having spread its wings, presented the forward edges to the wind, just as the bird would do in flight. He states that as a result he felt the bird pulled forward into the wind as he had anticipated. His soaring machines consisted of aeroplanes of concave shape, similar to a bird's wing, to which he attached himself.

To start his flight he obtained an initial velocity by being driven in a cart or glided from a convenient height. A very interesting account is given at length of these trials in Chanute's book, " Progress in Flying Machines," page 104, &c. Le Bris seems to have abandoned his experiments through financial straits and bad luck, also loss of energy due to advancing age, rather than to failure of his ideas. That lifting effort can be produced by the action of an air current upon the edge of a curved surface, as distinct from the lifting effect produced by an air current moving against an inclined flat surface, has been demonstrated by Mr. Horatio Phillips in England. He does not, however, appear to have experienced or relied upon the aspirating effect mentioned by Le Bris. His ideas seem to have been confined to producing a lifting effect, and rather to the contrary he shows that the lift of his planes was accompanied with some amount of backward thrust or drift. Nevertheless, his principle is quite a distinct and novel one. He states as a result of his experiments, extending for 27 years, that anything approaching a flat surface is useless for supporting heavy loads in the air. His idea consists in the use of a narrow surface, curved both above and underneath. When such a plane encounters a current of air directly against its forward edge there is produced a difference of pressure between the upper and under surfaces, and the plane tends to rise. By multiplying the number of planes any desired amount of lifting effect should be produced. He proved that this idea was correct by experiments upon a variety of shapes of plane, and constructed a machine which actually flew round an experimental track. The advocates of each system, "lighter than air," or "heavier than air," have scored a partial success, and including, as they do, men of undoubted ability on either side, have removed the stigma which at one time attached itself to every experimenter in the art of aerial navigation.

In Germany, at Berlin, Otto Lilienthal has devoted his attention to most painstaking study and experiments with soaring apparatus. He convinced himself that flat surfaces present undue resistance, his final aeroplanes being of the concavo-convex form. The trials were made on hilly country against the wind, the experimenter launching himself and his apparatus from the top of a hill itself, or from the roof of a tower constructed for the purpose on the hill. He was successful in soaring to heights of 65 to 82 feet. During 1891 he tried aeroplane wings, having an area of 172 square ft., the apparatus weighing 53 lbs. Including himself the total weight raised was 229 lbs., which shows that the aeroplane would sustain and lift a weight of 1·33 lbs. per square foot of area, the wind velocity being calculated as 23 miles per hour. A tail having vertical and horizontal planes was necessary to keep the apparatus steady. Lilienthal generally proportioned his aeroplanes to have three-quarter square foot of surface per pound weight to be raised and sustained. The propelling power calculated (furnished by the wind) was at the rate of 6 H.-P. approximate, to every 1,000 square feet of surface. Lilienthal was killed by a fall when making one of his flights on August 9th, 1896; the cause was apparently due to a sudden gust of wind striking the aeroplanes and overbalancing the apparatus in a backward direction.

PLATE V.—The Deutsch Airship "Ville de Paris."

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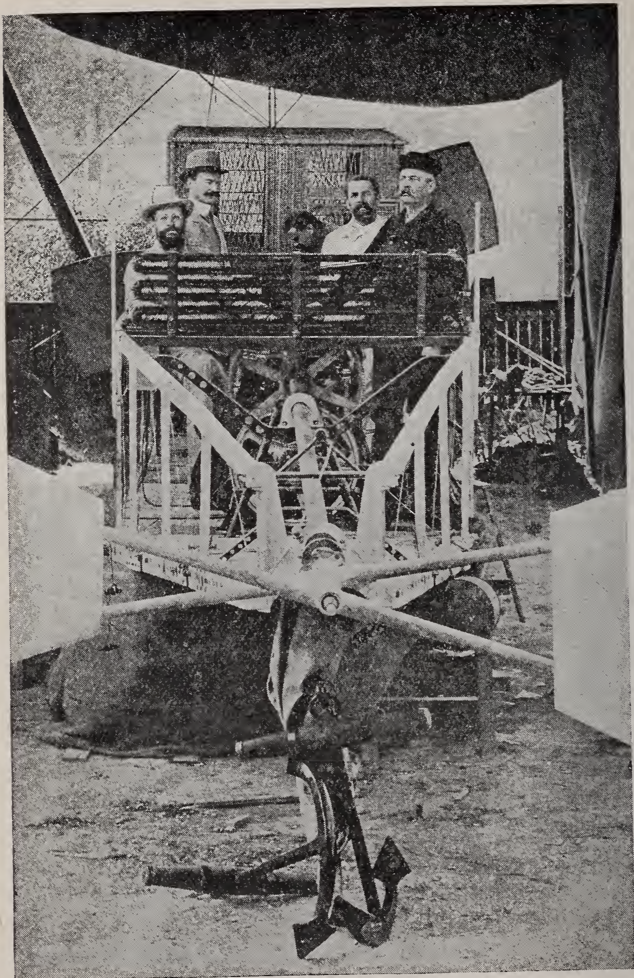

PLATE VI.—The Wellman Airship.

An end view of the Car with Mr. Wellman on board (see extreme right of Car).

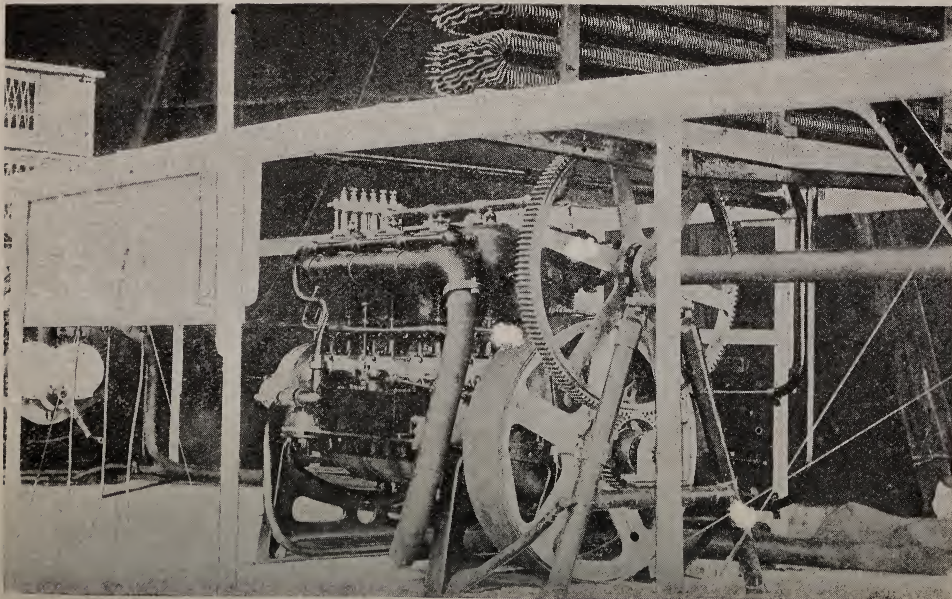

PLATE VII.—One of the Motors for the Wellman Airship.

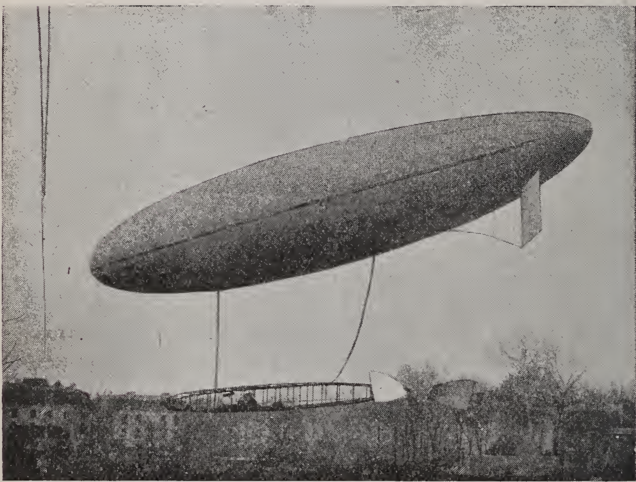

PLATE VIII.—An Earlier Deutsch Dirigible.

CHAPTER II.

Dirigible Balloons.

Henry Giffard.

A name which is well known amongst engineers is that of Henry Giffard, the inventor of the injector apparatus for feeding water into steam

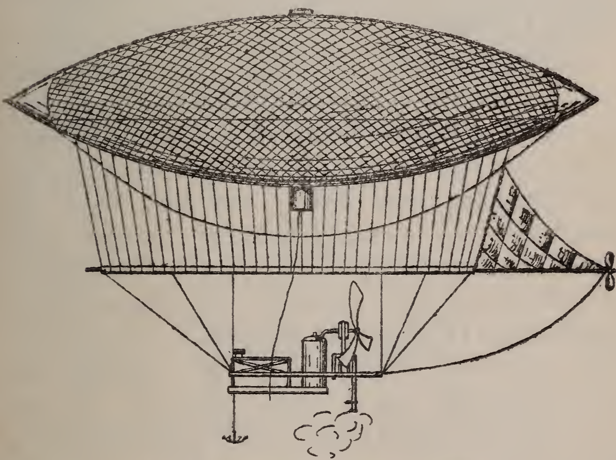

Fig. 1.—Giffard's Dirigible Balloon.

boilers, an invention which is in use all over the world at the present day. This engineer devoted his attention to aerial navigation in 1850 and constructed a dirigible balloon (Fig. 1). It was of elongated shape, 39 ft. in diameter at the largest part and 144 ft. in length over all. Motive power was provided by a steam engine driving a screw propeller having two blades and a diameter of 11 ft. To avoid risk of fire the funnel of the boiler was bent downwards and draught produced by a steam blast. Steering depended upon a rudder of sail construction. Mr. Giffard ascended from Paris on 24th September, 1852, obtaining a speed of 4½ to 6¾ miles per hour with a screw speed of 110 revolutions per minute.

Dupuy de Lôme.

Another engineer of repute, Mr. Dupuy de Lôme, a French naval architect, commenced upon the design and construction of a dirigible balloon during the siege of Paris in 1870, it was however not completed until 1872. He dealt with his experiments in a very thorough manner and applied his knowledge and experience of navigation in water to navigation in air. The balloon of elongated shape (Fig. 2), had a maximum diameter of 48ft. and a total length of 118 ft., the capacity for containing gas, was 120,000 cubic ft. It was propelled by a screw made of sails 29½ ft. diameter, 26 ft. pitch, driven by 8 men at 27½ revolutions per minute. The surface of the propeller blades was 160 square ft., total and slip ratio 23 per cent., the balloon advancing 20 ft. for each revolution of the propeller. In the trials a speed of about 6¼ miles per hour was obtained and it was considered that the rudder had enabled the course to be altered by 12 degrees approximately, the day being windy. This balloon had an available ascending power of 5,515 lbs. The weight of the structure was 3,885 lbs. The men who worked the propeller weighed together 1,325 lbs., and are supposed to have produced $\frac{8}{10}$ H.-P. Apparently the trial was

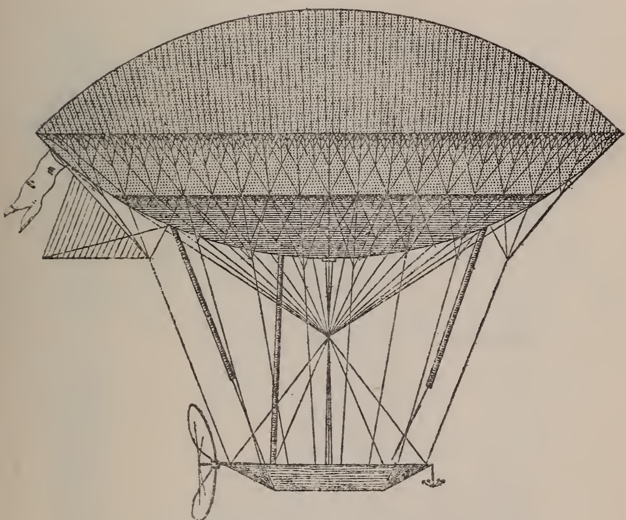

Fig. 2.—Dupuy de Lôme's Dirigible Balloon.

satisfactory, the calculated and observed velocities being almost identical.

Gaston Tissandier.

Some experiments were made in 1881 by Gaston Tissandier, in France, who also used a screw propeller to drive his balloon (Fig. 3). But practical electric motors having come into existence, he applied electricity to drive the propeller, partly because there was less risk of fire than with a steam engine. Another advantage is that an electric motor does not give out products of combustion, which disturb the ballasting of the balloon. Ex-

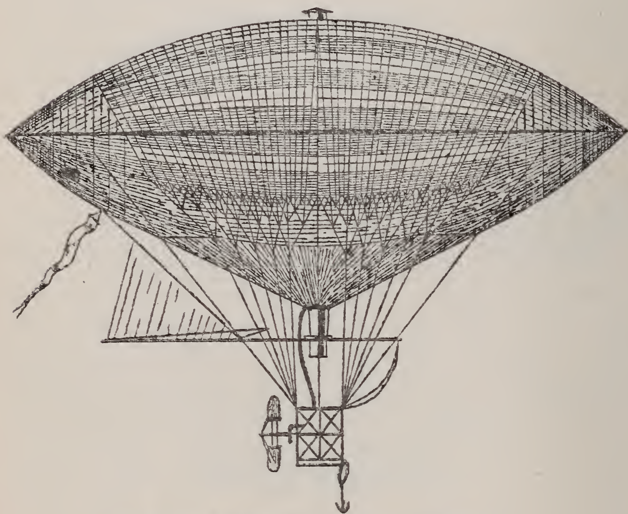

Fig. 3.—Tissandier's Dirigible Balloon.

periments were first made with a model, the large balloon being constructed afterwards with the assistance of the information gained. This experimental model balloon was of elongated form, about 11 ft. in length by 4 ft. 6 ins. diameter at the largest part. It had a capacity of 77½ cubic feet, pure hydrogen being used to inflate it, giving a lifting power of about 4½ lbs. The screw propeller was driven by means of a very light electric motor weighing about ½ lb., and was provided with two blades, the diameter being 18 ins. A

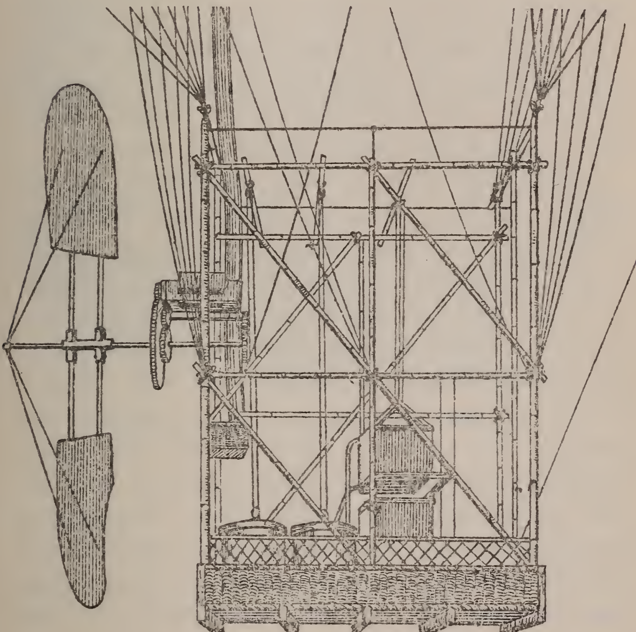

Fig. 4.—Propeller and Gearing of the Tissandier Balloon.

battery of accumulators weighing nearly 3 lbs. gave electric current to the motor. With the propeller rotating at 390 revolutions per minute the balloon attained a horizontal speed of two miles per hour for 40 minutes. With an accumulator battery of two cells weighing $1\frac{1}{3}$ lbs. and a propeller having a diameter of 21 ins., the speed was approx. 4·4 miles per hour for 10 minutes. A further trial with a battery having three cells gave a speed of 6·8 miles per hour approx. Reported tests of the motor seem to show that it was doing work at the rate of about 314 foot lbs. with a single cell connected to it, and its shaft running at 300 revolutions per minute. With three cells it was giving about 700 foot lbs.

Some particulars of the equipment are as follows: Balloon of elongated pattern, 91 ft. in length by 30 ft. diameter at the largest part; weight, 2,728 lbs.; screw, 9 ft. diameter; weight of motor, 119 lbs., geared by spur wheels to run at 1,800 revolutions per minute when the screw was making 180 revolutions per minute. Fig. 4 shows the arrangement of the propeller of gearing. At the trials made in 1883 the speed obtained was about $6\frac{1}{2}$ miles per hour, and in 1884 about eight miles per hour. Apparently the experimenters were able to keep the balloon head to wind, and at these speeds to steer easily when running with the wind and to return to the place of departure.

It was, of course, necessary to provide some means of generating the electricity required by the elctric motor. M. Tissandier used a primary battery of 24 cells, arranged so that the number in use at any moment could be varied, thus regulating the speed of the motor by altering the voltage applied to its terminals. The highest voltage would be about 40 volts, as the cell used was of the bichromate of potash form, which gives nearly two volts.

Renard and Krebs.

Another electrically driven balloon (Fig. 5) was tried by Captains Renard and Krebs, whose experiments were made in France during 1884 and

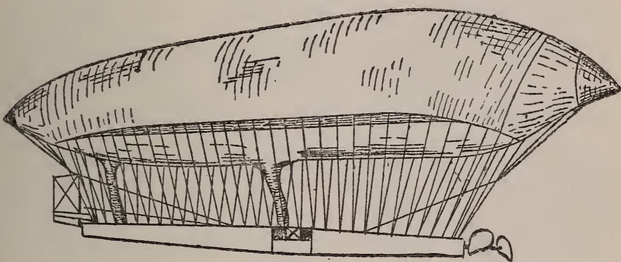

Fig. 5.—Renard and Kreb's Dirigible Balloon.

1885. The total length of the balloon was 163 ft. and largest diameter 27 ft.; ascending power, two tons (4,480 lbs.); volume of balloon, 65,799 cubic feet; length of car, 36 ft. Various parts weighed as follows: Balloon, 1,912 lbs.; silk covering and network, 280 lbs.; car and suspending gear, 335 lbs.; rudder, 101 lbs.; propeller, 90 lbs.; electric motor, 216 lbs.; gearing and shaft, 170 lbs.; battery of 32 cells, complete (accumulators of special design), 958 lbs.; diameter of propeller, 23 ft. The battery was designed to give nearly 9,000 watts to the motor during four consecutive hours; about 9 B.H.-P. would be therefore available to rotate the propeller. A number of trips were made with this balloon. On one occasion it travelled from Paris to Chalais and back, encountering a head wind of three to three and a-half miles per hour velocity, the voyage being repeated upon the following day. Maximum height attained, 1,308 ft. A speed of over 13 miles an hour was obtained, the balloon answering the rudder and returning to the point of departure in five out of seven trips. The balloon was successfully driven against a wind having a velocity of 11 miles per hour. A maximum speed of about $11\frac{3}{4}$ miles per hour was reached, but in other trials the average speed was about $15\frac{1}{2}$ miles per hour. Speed of screw propeller, 30 to 40 revolutions per minute. To measure the speed of the balloon an aerial log was used. This consisted of a small balloon made of gold-beater's skin filled with about 200 pints of common gas and held in equilibrium. Attached to it was a silk thread, 109 yds. in length, and wound upon a reel. This small balloon being liberated would recede from the car; as soon as the thread had run out its length a pull would take place. As the end of the thread had been attached to the finger of the observer he would feel the pull, and could note the time taken for the length of thread to run out, and thus ascertain the speed at which he was travelling. The electric motor shaft rotated at a maximum speed of 3,000 revolutions

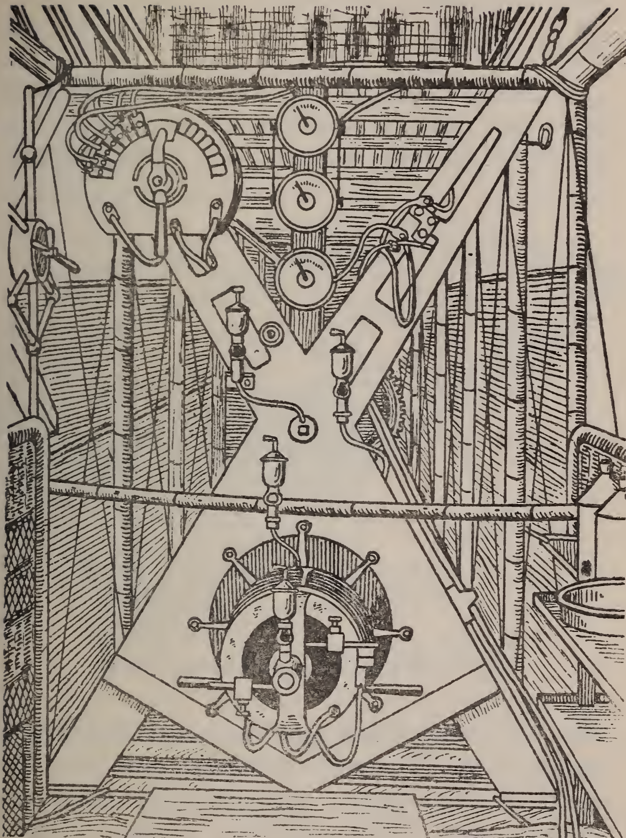

Fig. 6.—Renard and Kreb's Motor and Regulating Apparatus.

per minute. The arrangement of the motor and regulating apparatus is shown in Fig. 6.

Santos Dumont.

M. Santos Dumont has constructed and made trials with several dirigible balloons, all driven by screw propellers rotated by petrol engines.

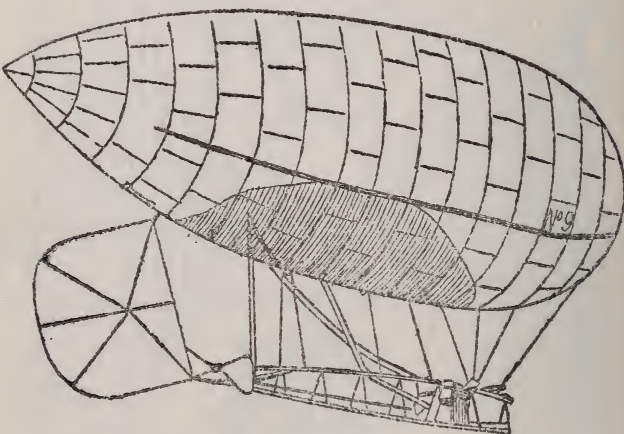

Fig. 7.—The No. 9 Santos Dumont Balloon.

His No. 9 was of comparatively small size (Fig. 7) designed to be easily controlled and used for short-distance trips. As originally made, its capacity was 7,770 cubic ft., giving a lifting power to take about 66 lbs. of ballast. It was afterwards enlarged to 9,218 cubic ft. capacity. The petrol engine was of 3 H.-P. size, weighing 26½ lbs., and a load of 132 lbs. of ballast was carried. This balloon had a speed of 12 to 15 miles per hour, and was driven with the large end forward to make it respond more readily to the rudder. M. Santos Dumont made a number of trips, running for a whole afternoon without losing any gas or ballast. He actually proceeded along the streets of Paris to his house early one morning and alighted at the door, leaving the

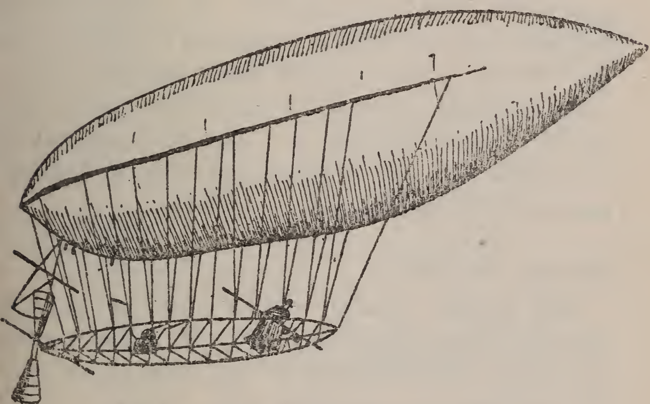

Fig. 8.—The No. 6 Santos Dumont Balloon.

balloon in the roadway whilst he entered and partook of breakfast, then entering the car again ascended and made his way to the starting place. He used a guide rope 132 ft. in length, and found that it worked best when about 66 ft. trailed along the ground.

A larger balloon was the No. 6, with which M. Santos Dumont won the Deutsch prize by travelling from the Aero Club grounds at St.

Cloud, Paris, to the Eiffel Tower and back, rounding the tower *en route*, the total distance of seven miles, plus the turn round the tower, being traversed in half-an-hour. The overall length of the balloon (Fig. 8) was 110ft., and the largest diameter 20 ft.; capacity, 22,239 cubic ft., giving a lifting power of 1,518 lbs. Screw propeller driven by a 4-cylinder 12 H.-P. water-cooled petrol motor gave a tractive effort of 145 lbs. A compensating balloon was used having a capacity of 2,118 cubic ft.; it was placed in the main balloon at the underside, and a pump driven by the engine continually passed air into it. The air was allowed to escape through a valve, and thus a definite pressure was maintained.

Spencer and Sons.

The Mellin airship constructed by Messrs. Spencer & Sons, of London (Fig. 9), is also a comparatively recent example of the dirigible balloon. It was made of varnished silk; length, 75 ft.; maximum diameter, 20 ft.; weight, with netting, 290 lbs.; capacity, 20,000 cubic ft.: the car was 42 ft. in length, made of bamboo; motive power, a Simms petrol motor having water-cooled cylinder and magneto ignition; speed of engine, 2,000 revolutions per minute, driving the screw propeller at 200 revolutions per minute. Propeller of light pine: weight, 28 lbs.; diameter, 8 ft., and 4 ft. in width at the ends.

The following data for the construction of dirigible balloons have been calculated in accordance with the actual trials of Messrs. Giffard and Dupuy de Lôme, and with the results given by steam engines of the most improved type at the time the calculations were made. They are taken from the Proceedings of the Institution of Civil Engineers, Vol. LXVII. (1882), page 373.

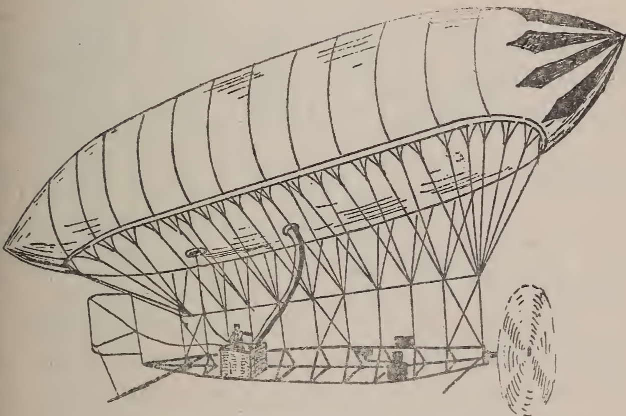

Fig. 9.—The "Mellin" Airship.

The paper is by William Pole, F.R.S., and deals at length with the subject, giving a considerable amount of information.

The 40-ft. diameter size corresponds to Giffard's balloon; the 50-ft. diameter to Dupuy de Lôme's balloon. According to these calculations he would have obtained better results by using more favourable proportions and modern steam power. He could thus have carried an engine of 32 H.-P., which would have driven the propeller at three times the speed, and produced with the higher pitch a velocity of 20 miles per hour.

	feet.	feet.	feet.	feet.	feet.
Maximum diam of balloon	30	40	50	75	100
Length ...	110	147	183	275	367
	lbs.	lbs.	lbs.	lbs.	lbs.
Total ascending force ...	2970	7040	13750	46400	110000
Weight of structure ...	2370	4220	6600	14850	26400
Available ascending force	600	2820	7150	31550	83600
H.P. of motor ...	3	12	32	140	370
	cwt.	cwt.	cwt.	tons.	tons.
Weight disposable for cargo after allowing fuel and water ...	2½	12½	32	7	18½
Maximum speed through the air in miles per hour ...	12	17	20	25	29
Diameter of screw in feet	18	24	30	45	60
Revs per minute for maximum speed ...	76	81	77	64	55

Giffard's balloon was inflated with coal gas only. A velocity of 10 miles per hour should have resulted; it was so much less because of the small size of the propeller, which was only about one-fifth of the correct area.

With regard to the proportions of a balloon, length gives better steering properties and diminished resistance in proportion to capacity. The proportion of length to diameter was 3·66 in Giffard's balloon, and 2·43 in Dupuy de Lôme's balloon.

Dr. Barton.

Among the many laudable attempts made in this country to solve the problem of the air was that of Dr. A. Barton, of Beckenham, who, in conjunction with Mr. F. L. Rawson, in 1904 and 1905 built a dirigible of very large dimensions. During the former year the writer was present at the personal demonstration of this huge airship by Dr. Barton, at Alexandra Palace.

As most readers will remember the machine was of "the lighter than air type" depending for vertical support upon a cylindrical balloon.

The balloon was 43 ft. in diameter and 176 ft. long; with a cubic capacity of 235,000 ft.; its general shape being shown by the accompanying photograph (Plate I). When filled with hydrogen gas the lifting power of balloon was approximately 16,400lbs. or about 14 per cent. in excess of the weight of the framework it supported. To keep the envelope quite taut a smaller balloon was placed inside the main one. This auxiliary balloon was arranged so that it could be inflated or deflated with air to compensate for variations of temperature and loss of gas, and so prevent any trouble when the machine was tilted. The envelope was made of tussore silk and required 600 carboys of acid and 50 tons of iron borings to completely inflate it with hydrogen gas. The framework was constructed of bamboo, the diameters of these timbers varying from 1½ ins. to 5 ins. The carriage was attached to the gas-bag by about 80 steel wire cables. The deck was made of latticed wood, and a light bamboo framework, filled in with wire netting, enclosed it on all sides. The bamboo members which formed the frame were lashed together with cord at the joints. The keel was 120 ft. long; the deck 123 ft. long; and the upper frame 127 ft. long.

Four propellers were provided, two at each end of the ship. These were of compound construction, built up of three two-bladed propellers, the blades of each lying behind one another. The bearings for the propeller shafts were mounted on 4 steel tubes (A Fig. 10), which passed right across the ship and were held together at each end by aluminium castings, which were braced by tie rods; indeed the whole structure was an elaborate system of cross bracings, bamboo rods corded together at the joints and steel wires forming the major portion of the materials used. Two 50 H.-P. motors of the latest Buchet type were fitted, the the motors being bolted down to strong aluminium castings, which were clipped to the large bamboo members, a pair of these castings being used for each motor. The motors were fixed with their

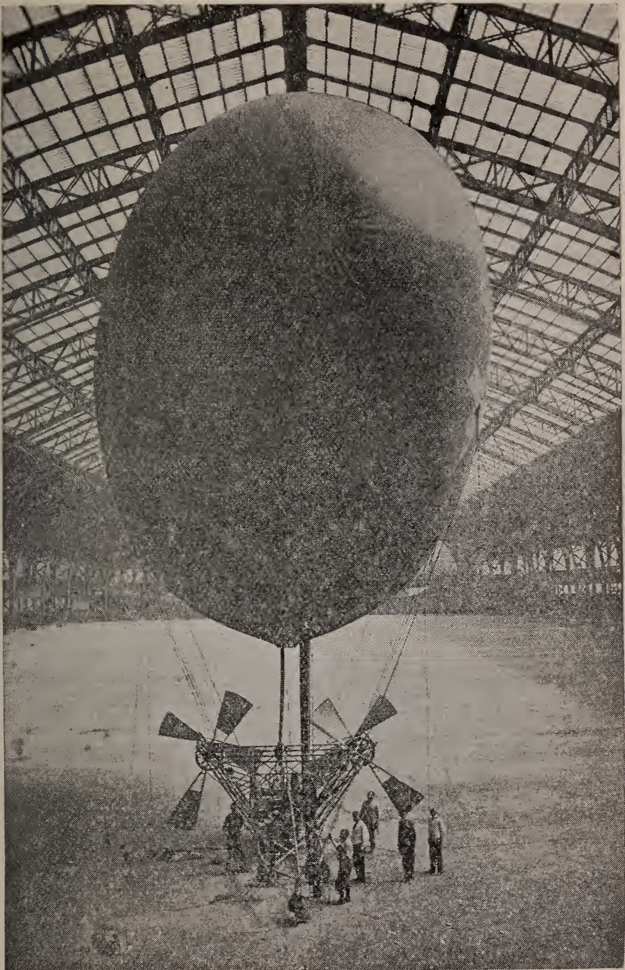

PLATE IX.—The Francois-Lambert Dirigible "Ville St. Maude."

Facing page 40.

PLATE X.—Maxim's Steam Flying Machine.

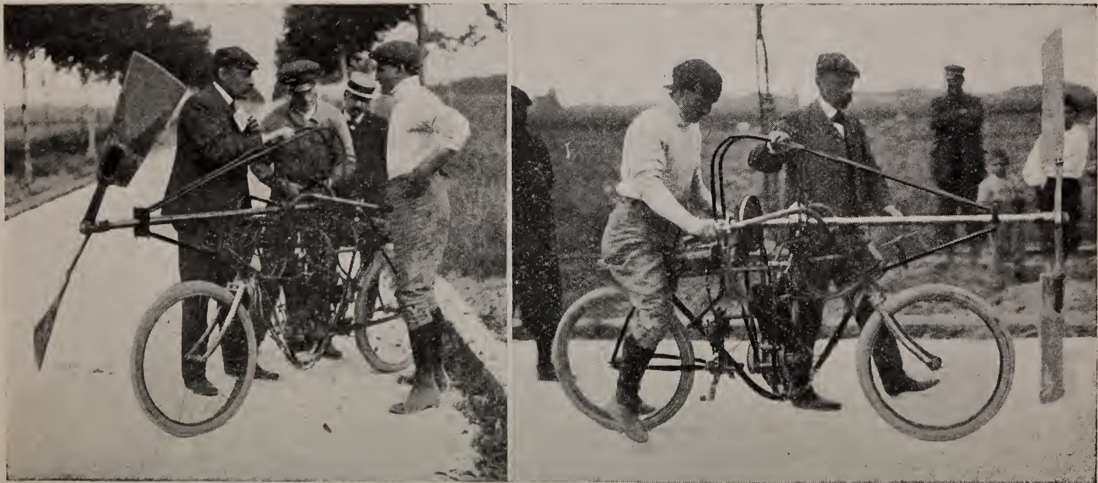

PLATE XI.—Archdeacon's Air Propeller Cycle.

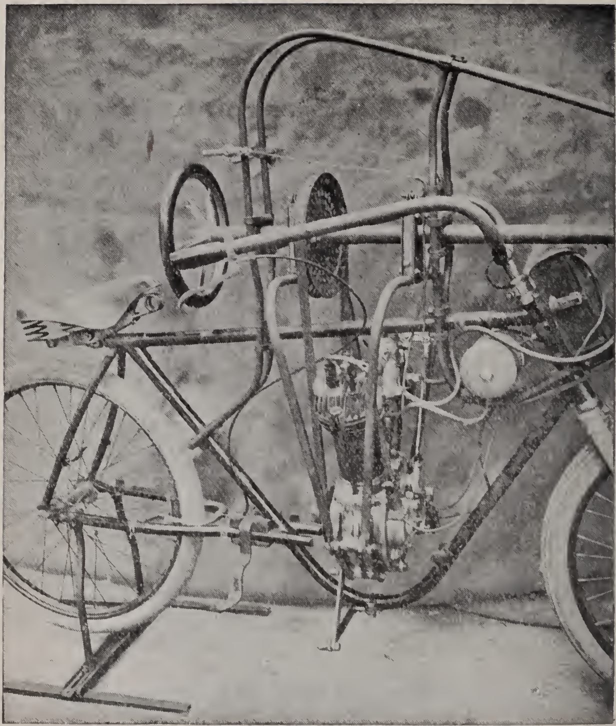

PLATE XII.—Machinery of Archdeacon's Air Propeller Cycle crankshafts lying parallel with the keel, and were provided with large friction clutches, the power being transmitted through gearing and by belts to the propeller shafts. The engines were destined to run at a normal speed of 1,600 revolutions per minute, the velocity ratio of the transmission system to the propellers being 8 to 1. Each of

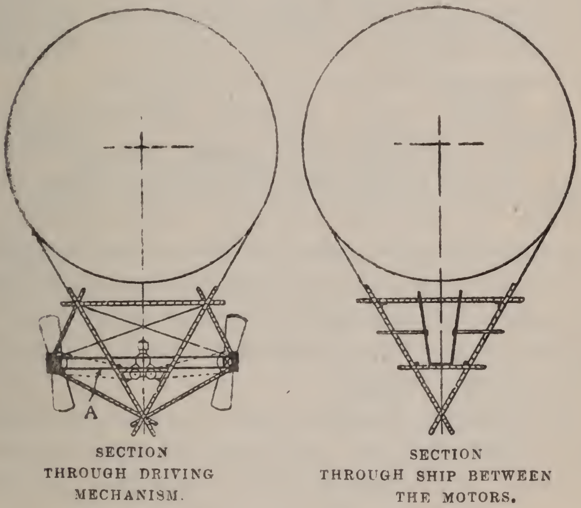

Fig. 10.—The Barton-Rawson Airship.

the motors were under the control of a separate man and the speed of the propellers was arranged to be controlled by regulating the throttle and spark advance of the engine in the usual way.

The horizontal balance of the air ship was preserved in a very novel manner. Two fifty gallon tanks, half filled with water, were fitted one at each end of the carriage. These tanks (Fig. 11) were connected by a single line of piping working through a semi-rotary hand pump placed amidships. A man was stationed at this pump and when the craft tended to tip one way or the other, the water was transferred from the tank at the lower end to the higher one. In this way the air ship could be readily maintained in the horizontal position and any surging of the gas in the gigantic balloon above prevented.

To obtain various altitudes without the expenditure of ballast, the airship was provided with several aeroplanes, the balloon being intended to have just sufficient lifting power to counterbalance the weight of the carriage and its accessories, the engines therefore being relied on to supply the necessary power in propelling it forward in the direction required and for lifting it to the desired height.

As originally designed, there were no less than 30 "Venetian-blind" aeroplanes arranged in three banks of ten, each set being mounted, so that they normally laid flat, in a horizontal plane, but could be simultaneously canted to any angle, up or down. For this purpose the aeroplanes were pivotted to the frame, some at the forward edges and some in the middle. Each aeroplane measured 15 ft. long by 3 ft. wide, giving a surface of 45 square ft., or an aggregate of 1,350 square ft. in all.

The aeroplanes were originally fixed between the deckline and the top of the carriage, as shown in the photographs of the excellent model (Plates I, II, and III).

For the ascent of Saturday, July 22, 1905, four aeroplanes like sails were provided. But while the experiments were, on the whole, considered to be satisfactory, the use of such a heavy carriage as that employed in the Barton-Rawson navigable

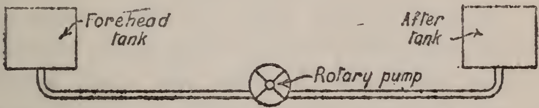

Fig. 11.—The Balancing Tanks of the Barton-Rawson Airship.

balloon does not seem to have been justified, and no further developments are recorded.

In any case the dirigible did not return, on this occasion, to the starting point, but drifted away and came to grief in landing. Furthermore, the reports which were at one time prevalent that the airship was intended for the British War Department were not confirmed.

Paul and Pierre Lebaudy.

It is not possible, owing to limitations of space, to describe the earlier experiments of MM. Paul and Pierre Lebaudy with their dirigible balloons in France. From first to last their airships have been uniformly successful, and the mishaps they have had, especially the more serious one which practically destroyed the first vessel, were not due to radical defects in the design of the respective craft.

The largest and latest dirigible, "La Patrie" (Plate IV) is the second airship of the fleet the French War Ministry is having built for service on the Eastern frontiers. The previous vessel, "The Lebaudy," which on trial kept the air for a period of over three hours, circling to and fro between Moisson and Frenuese in a wind blowing at the rate of eight miles per hour, and attained a velocity of 26 miles per hour with the wind and 11 miles per hour against it, formed the basis of the design for "La Patrie."

The new vessel, however, has a rather large volume of gas at the rear end of the envelope, the cubic contents of which is 3,200 cubic metres (113,000 cubic ft.). The length of the envelope is 60 metres (196 ft.), and diameter at thickest part 10·3 metres (33 ft. 9 ins.). The envelope is so reinforced that it will remain inflated for over three months.

To give the vessel greater vertical and lateral stability, the new airship has at the rear end of the balloon four fins, as shown in the photographs. The other noticeable features of the "Patrie's" gas envelope are the vertical and horizontal steadying planes under the balloon and the peculiar prow. Below the gas envelope is the usual car, but it is of very small size compared to that of the supporting balloon. Under the deck extends a frame of steel tubes. This is shaped like an inverted pyramid, upon the apex of which the whole car can rest when it is on the ground. In this frame is fitted the petrol tank.

The propelling engine consists of a 75 H.-P. Panhard petrol motor (that is, 20 H.-P. more than used in the earlier airship "Lebaudy") driving two screw propellers, one on each side of the navigator's car. These propellers are mounted on a frame of steel rods, and are actuated by a shaft passing out at the sides of the car and through bevel gearing. The motor is an exceptionally flexible one, and can be made to work the propeller satisfactorily at speed varying from 200 to 900 revolutions per minute. The exhaust pipe is carried to the back of the car, and ends in an efficient muffler.

In the "Patrie," the flat plane which forms part of the underside of the balloon is situated nearer to the front end, with the car suspended not from the middle, but rather towards the rear end. The keel frame, or plane, ends in a large rudder, which is of the balanced type, and is actuated by cords from the car. Most of the tensional members of the frame are made of wire rope for sake of strength and lightness.

Among the minor improvements, the "Patrie' is fitted with an electric alarm bell, which warns the navigators whenever the pressure of gas in the balloon reaches a predetermined maximum.

The lifting capacity is given at 1,260 kilogrammes (2,772 lbs.), so that the airship, besides carrying a petrol supply for 10 hours, can take a crew of three persons and 850 kilogrammes (1,870 lbs.) of ballast or other material, or a larger crew and a proportionately small load.

The first trials of the "Patrie" were made on November 16, 1906. At 8.20 a.m. the airship was taken out of the special shed erected for it. The weather was fine, with a fair breeze blowing, and after several preliminary trials close to the ground to test the working of the propellers, it was let go. On board were Georges Juchmès (the pilot), Captain Voyer (the delegate of the War Ministry), the future military commander of the airship Lieut. Bois (of the Aeronautical Department of Chalais Meudon), and two mechanics, and proceeded at a height of just over 100 metres (328 ft.), manœuvring quite successfully against the stiff breeze. The vessel then encircled the village of Lavacourt at a speed of 15 miles per hour, and, returning, stopped dead over the shed. It was housed without a hitch, and on the 22nd of the same month was again put through further tests, and in the second trip of the day, from 2 p.m. until nightfall, owing to the use of the planes, it was found that only 22 lbs. of ballast had been expended. The Panhard-Levassor motor was worked at about two-thirds speed, and with a maximum speed of only 30 miles per hour, the high average of 22 miles per hour was maintained throughout the trip. During its fourth trial, on November 24, it faced a 20-mile-an-hour wind, and on November 26 made the best performance of all, sailing a distance of 57¾ miles in 132 minutes. At the time of writing, the third ship for the French Government, which will be named the "Republique," is in hand, again to the designs of M. Julliot, the engineer of the "Lebaudy" and "La Patrie."

Count de la Vaulx.

Another French aeronaut, Count de la Vaulx, has recently made over 10 ascents, all perfectly successful. Count de la Vaulx, it will be remembered, was one of the earlier experimenters with dirigible balloons, and carried out a large series of demonstrations, mostly in the Mediterranean, of ordinary balloons made more or less navigable by means of a triple system of floats on the water.

The present machine is in many respects similar to the earlier Deutsch airship, but it is much smaller than the "Ville de Paris."

It was tried with success in July, 1906, and remained afloat for over seven and a-half hours with the Count and M. Maurice Mallet on board. An evolution test was made in the following January, and although no definite data are available, owing to the brisk wind prevailing at the time, the trials are said to have been entirely successful.

Since then the airship has covered 12½ kilometers (7¾ miles) in 22 minutes at an altitude of from 200 to 300 metres (650 to 980 ft.). On this occasion, February 4, 1907, 73 kilogrammes (160 lbs.) of ballast were carried, and 50 cubic metres (1,765 cubic ft.) of hydrogen gas were added to the balloon, only this small amount being required after it had been inflated for 47 days. Six days later two journeys, to Montesson and to Vesinet and back, were made with only 55 kilogrammes of ballast (120 lbs.) on board. The gas vessel has a capacity of 725 cubic metres (25,580 cubic ft.), and in practice only a small amount of ballast out of that carried was used. Most of this was only employed to modify the descent in alighting.

The general arrangement of the airship is a cigar-shaped balloon of regular outline, with a girder or rod slung from it, having a propeller at the fore end and a rudder at the other. The car containing the engine is a small one, hung below this, and the power is transmitted, therefore, by a telescopic shaft and two sets of bevel gearing.

Since the trials of this dirigible, Count de la Vaulx has, it is reported, become converted to the tenets of the "heavier-than-air" school, and is engaged on a new aeroplane machine, the details of which are contained in the following chapters.

Count Zepperlin.

Count Zepperlin, the famous German military officer, who has devoted a considerable portion of his life and one fortune in attempting to solve the many difficulties of the problem, is responsible for the huge airship with which he has for some time past experimented over the placid waters of Lake Constance.

His first notable airship was tried in 1900, and although only three flights were made in that year, and the results obtained were more or less satisfactory, they were marred by a series of unfortunate accidents. One trial was made on June 30 of the above year. In July the craft was propelled against a breeze stated by various authorities to be blowing 12 to 16 miles per hour at the rate of two miles per hour.

During one flight it remained in the air over an hour, although by some mishap the steering gear was partly unmanageable. The attempts showed, however, that the huge airship was, within the limits of its speed, dirigible, several complete circles being made in the air during the ascent.

The vast expense in building and experimenting with such an airship, and the outlay for the balloon house and accessory machinery, quite exhausted the inventor's resources, and Count Zepperlin was not able to proceed to any further developments until November of 1905.

The proportions of the airship of 1900 were truly remarkable. The gas envelope was of polygonal shape in cross section, and no less than 420 ft. long by 40 ft. diameter, it being bluntly pointed at the front and rounded at the rear. To enable the shape of the envelope to be retained it was built up of a framework of aluminium covered with oil cotton fabric.* The envelope was divided into 17 separate compartments.

The craft with which the recent experiments were made was about 10 ft. shorter, but, owing to the diameter being larger, the capacity was increased by 32,000 cubic ft. to 370,000 cubic ft. The total weight of the later airship is one ton less than the original vessel, the total being 19,800 lbs. with ballast and equipment. Liquid ballast was still employed, the water being contained in bags which could be opened by valves from the navigator's deck. The gas bag of the later ship was, it is understood, only divided into six compartments, each of which were fitted with suitable valves under the control of the man in charge.

Instead of having only two 32 H.-P. petrol engines † as motive power, the later machine employed over five times the power, with a total extra expenditure of weight of only 11 lbs., the figures being 170 H.-P. for a load of 880 lbs. One engine was placed at each end of the vessel, each actuating two propellers situated near to the gas vessel on either side.

The steering apparatus was in duplicate and so arranged that one man could actuate the fore and after rudders without moving.

During the ascent of November, 1905, trouble was again experienced with the steering gear on

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* Pegamoid, it is understood, was used in the later balloon.
† Two 16 H.-P. Daimler motors.

the forward portion of the vessel, which became partly submerged in the lake, although the rear of the airship was sustained in the air by the gas and one motor.

Last year the airship was afloat, at one time, for a period of two hours and attained an altitude of 1,000 ft. above the Lake Constance. During that time it appeared to be under perfect control, describing circular paths and other similar evolutions. It is also said to have held its ground against a 33 miles an hour wind, but this is a doubtful claim. Another report gives 12 miles per hour. The end of the airship was occasioned by the derangement of the longitudinal stability when it struck a tree and was destroyed.

Count Zepperlin, in announcing his retirement from the field of aeronautical experiment, admitted that his ship was too large, but it would appear that, perhaps owing to the success of the French in aerial navigation, the German military authorities are following up the work of Count Zepperlin.

Major August von Parseval, by the aid of the Government, has, we understand, built a dirigible balloon embodying some of the ideas of Count Zepperlin. This machine is 160 ft. long with a single propeller, 13ft. diameter, driven by a 90 H.-P. petrol motor. It has, however, no rigid framework.

As far as can be ascertained, at the test of June, 1906, the machine rose in the air about 1,000 ft.

and came back to the starting point. The capacity of the gas envelope is given as 8,000 cubic feet, and the dirigible is said to have a horizontal tail as well as a vertical rudder. The German military authorities, however, are guarding the details of the machine and complete information is not obtainable.

Henri Deutsch.

The new airship of Mons. Henri Deutsch de la Meurthe, built to the plans of Mons. Surçouf, shown in the accompanying photograph (Plate V) is one of the largest in France, the gas envelope measuring 201 ft. in length, 35 ft. maximum diameter, and having a capacity of 3,500 cubic metres (123,500 cubic feet).

The chief feature of the new dirigible lies, as will be seen by a comparison with Mons. Deutsch's earlier machine (Plate VIII) in the novel form given to the rear end of the gas vessel. The eight supplementary cylindrical balloons, which are placed cruciform fashion on the cylindrical tail of the main balloon, are intended to steady the craft and are thought to be preferable to the use of canvas covered frames or fins. The other noteworthy feature of design is the car frame slung from the balloon. This is a braced girder of rectangular cross section tapering to a point at each end.

The motor used on the "Ville de Paris," was a four-cylinder Argus developing 70 H.-P., and the propellers were geared down 5 to 1. In the earlier vessel the propeller was fixed to this frame at the end, but the removal of the rudder from a position just under the rear end of the gas envelope to end of the frame necessitated the placing of the propeller at the front end of the car frame.

The trials were attended with a series of unfortunate accidents. It commenced operations under control of the guide rope, the crew of the vessel being made up of four persons, Mons. E. Surcouf at the helm.

Considerable trouble was experienced with the carburettor freezing, owing to the cold weather and movement of the airship. This was further aggravated by the fact that the exhaust, which to prevent accidents from fire is water cooled, did not help in heating the carburettor. As a result the engine stopped every few minutes and the flight had to be discontinued.

Whilst in the air, however, the machine appeared to be quite steady, but in the operation of alighting, the guide rope caught in a tree and in endeavouring to free it, the navigators rendered the airship unsteady. It swooped down amongst some trees, damaging itself considerably, and came down in a neighbouring field, the high wind causing the gas vessel to buckle and become deflated. On examination it was found that the car had also suffered considerable damage and up to the time of going to press no further trials have been made. The guide rope method of control appears to be the weak spot in the design of the "Ville de Paris." It is in this, the matter of control, that the Lebaudy Brothers, with their "La Patrie," seem to have made such remarkable progress.

Francois Lambert.

The dirigible "Ville de St. Maude" (Plate IX) was exhibited in the Galerie des Machines prior to its dispatch to the St. Louis Exposition in 1904.

This airship was designed by Mons. H. Francois. The gas vessel was of the cigar-shaped type, rather fuller in the centre than those of the Santos Dumont dirigibles, which immediately preceded it. The total length of the envelope was 32·5 metres (106 ft. 6 ins.), with a capacity of 1,850 cubic metres (65,300 c. ft.) the internal balloonette holding about 10,000 c. ft.

The motive power was supplied by a four-cylinder Prosper-Lambert motor, giving 30 H.-P., mounted almost exactly amidships, and driving four propellers placed at the four upper corners of the triangular framework of the car. The forward propellers measured 3·1 metres (10 ft. 2 ins.) diameter, and those aft 3·75 metres (11 ft. 3 ins. diameter). The main framework of the case was 2·8 metres (9 ft. 2 ins.) long by the same dimensions in height. The petrol tank (60 litres capacity) and exhaust silencer were placed below this, and, to prevent them being damaged when the machine rested on the ground, these accessories were safeguarded by the provision of two trussed frames projecting below the main frame. Fore and aft of the main frame extended a trussed girder, shown in the photograph supporting the bags of ballast.

The two parallel propeller shafts were placed longitudinally on each side of the frame and and ran in ball bearings. They were arranged to revolve in opposite directions, one belt from the engine being crossed. The proper belt tension was maintained by jockey pulleys, and a fan was used to keep the balloonette full of air. The total weight of the airship was 1,450 kilogrammes (3,190 lbs.).

The airship arrived at St. Louis after several mishaps during transit, but no reports of any special success obtained with this dirigible are forthcoming.

Wellman.

In connection with the Wellman Airship Expedition to the North Pole, extensive preparations are at the time of writing being made at Dane's Island, a point midway between the North Pole and Cape North, Lapland. To cover the intervening 600 miles, a dirigible balloon, of which we include herewith a general view (Fig. 12) and photograph of the propelling machinery (Plate VI), specially designed to suit the needs of the expedition is being completed in a large hall 200 ft. long by 75 ft. wide and 85 ft. high.

The vessel has entirely novel features. The gas vessel is constructed to hold 224,000 cubic feet of hydrogen. Two motors (Plate VII) are employed, both of de Dion's manufacture, one giving 45 H.-P. and the other 60 H.-P.

To maintain the gas envelope in a full inflated condition—to allow for leakage and for the contraction of the gas by the cold—a separate 5 H.-P. motor is carried to compress air and conduct it to an internal balloonette which is formed in the lower part of the main balloon, the partition being shown by the dotted line in the drawing.

The car is a strong frame of constructed steel tubing and has a completely enclosed central section which comprises the engine room and living room.

The airship is designed only for moderate speed, or, which is the same thing, to hold its own against any ordinary unfavourable winds. About 10 to 12 miles per hour is expected.

For maintenance of a vertical equilibrium a modification of the usual guide rope is employed. As stated in Chapter I. the ordinary guide rope is simply a line or chain trailing over the surface of the earth; and when the balloon tends for any reason to rise, the extra weight of the rope which would have to be carried prevents the upward movement. In a similar manner any tendency for the airship to descend relieves it of some of the suspended weight and the effect is the same as removal of ballast, and the equilibrium is maintained.

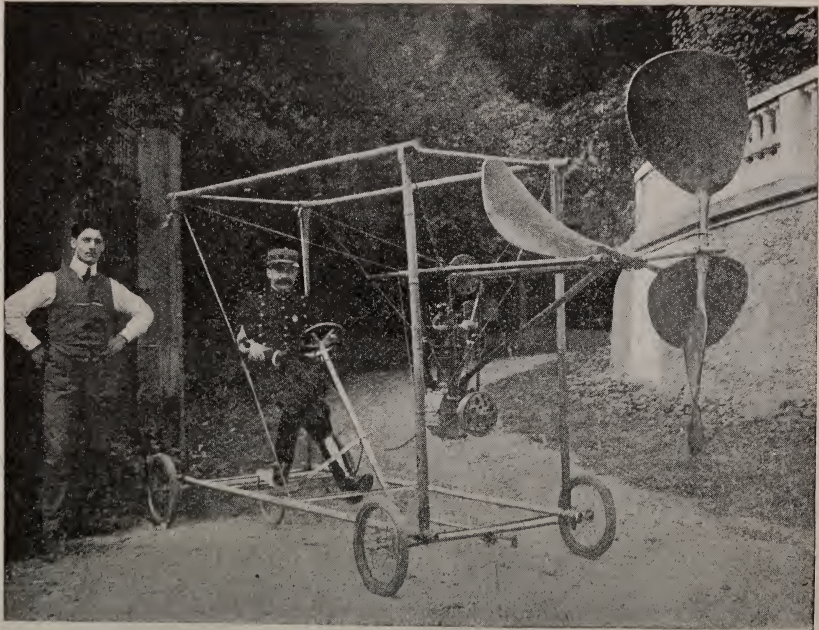


PLATE XIII.—Captain Ferber's Experimental Air Propeller.

Facing page 56.

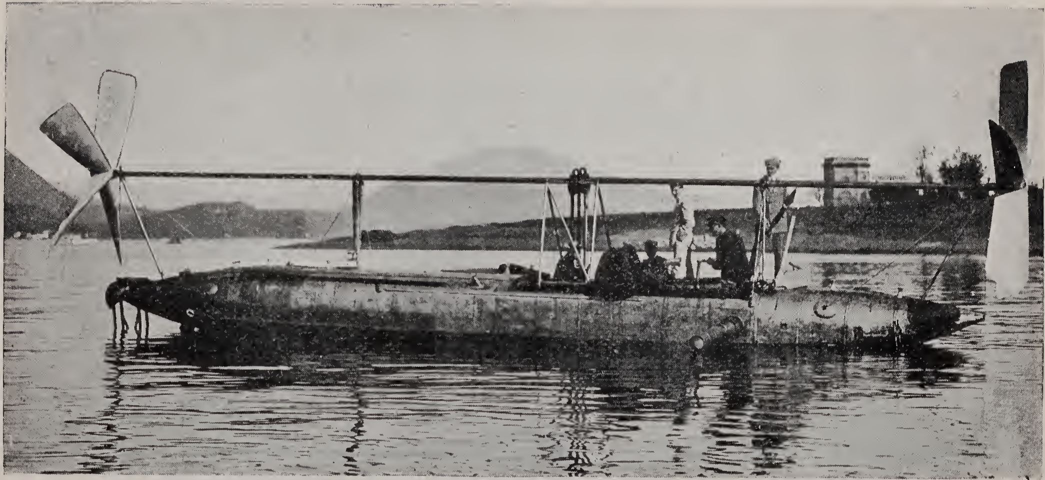


PLATE XIV.—Trolanini's Experimental Air Propeller Boat.

PLATE XV.—The Altered Bleriot-Voisin Aeroplane which was experimented with on Lake Enghein.

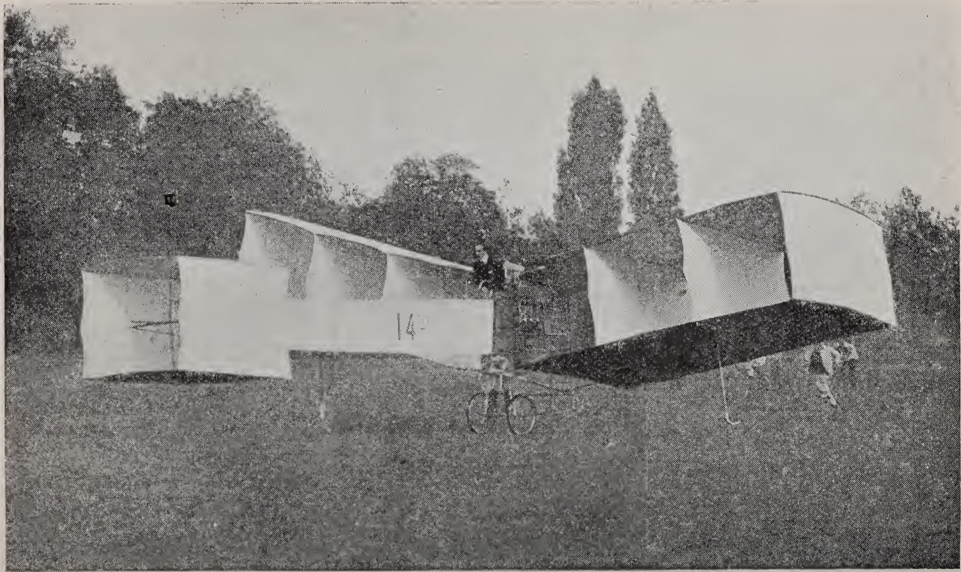


PLATE XVI.—The Santos Dumont Aeroplane, "No. 14 bis," travelling along the ground just before the actual flight.

In the Wellman airship the guide rope and its accessories will weigh about 1,200 lbs., and it is constructed to act equally well upon water as upon ice. The lower end will have four steel cylinders about 10 ft. apart attached to the steel

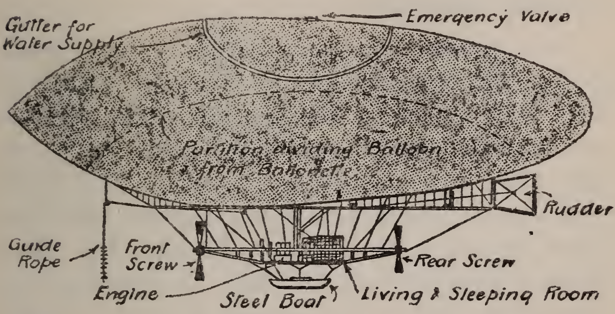


Fig. 12.—General Arrangement of The "Wellman" Airship.

cable, with wood runners outside. The cylinders will be so arranged that they will float in water. The excess cable of the "equilebreur" or guide rope —which, by the way, also acts as a retarder—will be carried in a steel boat hung below the car as indicated in the sketch (Fig. 12).

CHAPTER III.

Flying Machines.

Lawrence Hargrave.

Mr. Lawrence Hargrave, of Sydney, New South Wales, has attacked the problem by means of kites with which he has ascended into the air, and models which have been made to fly so that their action could be observed. The kites used were of box pattern, made of calico, stretched upon frames of American redwood. Mr. Hargrave connected four of these to a strong line, which was held to the ground by bags of sand. A sling seat was suspended to the lower kite so that the experimenter could be lifted by the combined pull of the four. Several ascents were made, on one occasion with the wind having a velocity of 18·6 miles per hour—a spring balance connected in series with the line indicated that the kites were exerting a pull of 180 lbs.; with the wind at 21 miles per hour, the pull indicated a force of 240 lbs. The kites weighed together 38 lbs., seat and line 7 lbs., aeronaut 166 lbs., making a total weight of 211 lbs., lifted by a kite surface of 232 square feet. Mr. Hargrave stated that he found this a safe method of experimenting, and appears to have ascended and descended without fear of accident, the kites being certain and stable in their action and needing no careful adjustment. These particulars of the kites used are taken from *Engineering* of February 15th, 1895, Vol. LIX., where Mr. Hargrave gives details of his experiences :—

Kite.	Breadth of each cell.		Depth of each cell.		Distance between the forward end of the forward cell to point of attachment of kite line.		Weight of Kite.		Length of each cell.		Distance between the cells.		Lifting surface of kite.
	ft.	in.	ft.	in.	ft.	in.	lbs.	ozs.	ft.	in.	ft.	in.	sq. ft.
A	5	0	1	10½	1	7	5	7	1	11	2	1	38·5
B	5	0	1	10½	1	7	5	14	1	11	2	4	38·5
C	7	8½	1	10¼	2	8	9	8	2	3	4	5	69·0
D	6	6	2	3½	2	3	9	0	2	6	3	6	65·0
E	9	0	2	6	2	10	14	8	2	6	4	0	90·0

This inventor's experiments cover a period of years, and were carried out in a scientific spirit, the subject being studied in a very thorough manner. He made a number of flying models which have flown experimental trials, giving his results for the benefit of other workers in the problem of aerial navigation. These machines give evidence of a high degree of constructive skill and mechanical knowledge on the part of their designer. In his first models he used elastic rubber bands as a motive power, 48 of them weighing about 10 oz., and each stretching to 30 inches with about 30 lbs. weight. The machine, Fig. 13, weighed 33½ oz.; 470 foot lbs. of energy could be stored in the elastic bands, and was sufficient to propel it through a flight of 270 feet horizontal. Total area of the sails was 2,130 square inches, and the centre of effort 14·6 inches behind the centre of gravity. A similar machine was also tried; it weighed 1·28 lbs., and flew 192

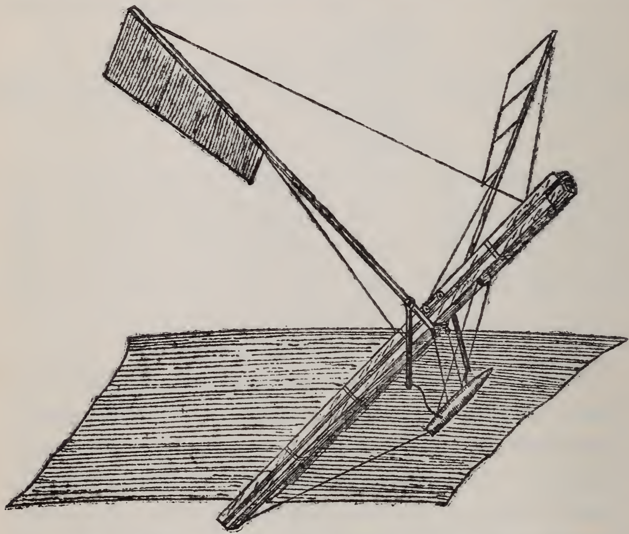


Fig. 13.—Hargrave's Model with Vibrating Wings.

feet in a horizontal direction, when the elastic bands gave out 193 foot lbs. of energy. The following results were obtained on other trials: Horizontal flights of 203 feet and 209 feet with an expenditure of 208 and 218 foot lbs. of energy respectively; sail area 1,980 square inches of surface, the centre of effort being 14·2 inches behind the centre of gravity. A small fore and aft sail was fitted for the purpose of obtaining steadiness of flight. This is an instance of forward motion being produced by means of vibrating wings moving up and down in a vertical direction. They were not provided with any direct

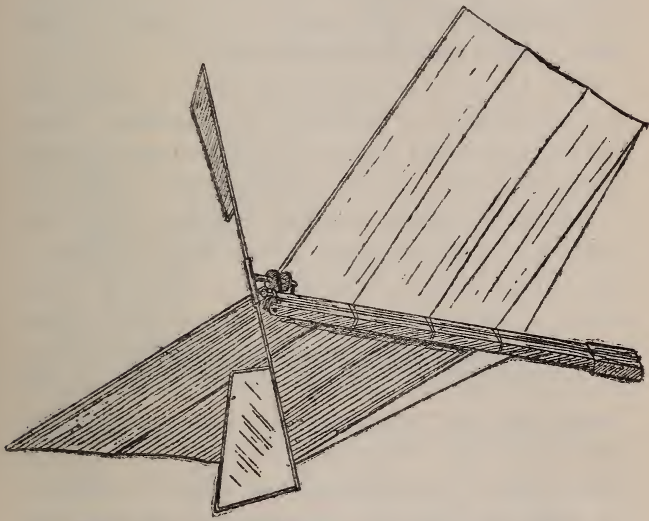


Fig. 14.—Hargrave's Machine with Screw Propeller.

twisting or feathering motion, but a feathering action took place due to the flexibility of the material of which the wings were made.

Mr. Hargrave, however, made experiments with a screw propeller as the means for producing the forward motion.

The model shown in Fig. 14 is fitted with a screw instead of wings. Its weight was 2 lbs., and sail area 2,090 square ins., the centre of effort being 10·5 ins. behind the centre of gravity. With an expenditure of 196 foot lbs. of energy, the machine flew 120 feet horizontal. In these three machines the percentage of sail area in advance of the centre of gravity was as follows: No. 1 model, 19·3 per cent.; No. 2 model, 20 per cent.; No. 3 model, 23·3 per cent.

Fig. 15 shows another machine, in which the forward motion is produced by vibrating wings, worked by a small engine, the motive power being compressed air. Some details of this model are as follows (complete working drawings are to be found in the Proceedings of the Royal Society of New South Wales, Vol. XXIV.): Area of body plane, 2,128 square ins.; of wings, 216 square ins. The backbone is tubular, and forms the reservoir for the compressed air; it is 48¼ ins. in length by 2 ins. diameter, and has a capacity of 144·6 cubic ins. The weight is 19½ ozs. At first 30 per cent. of the sail area was placed in front of the centre of gravity. But this arrangement did not prove successful, and the proportion was reduced to 23·3 per cent. The engine cylinder used for vibrating the wings has a diameter of 1½ ins.; stroke of piston, 1¼ ins.; weight of engine, 6½ ozs.; compressed air pressure, 230 lbs. per square inch. Movement is communicated to the wings by links, which connect the wing rods to the cylinder; the piston rod is fixed and the cylinder moves up and down, air under pressure being admitted from the reservoir to the cylinder, through a valve moved by tappets, during the entire length of each stroke. Vulcanite is used for the piston, with cup leather packing. As with the previous models, the wings, which are of paper, have no direct feathering motion, but depend upon the give of the material. Their weight is 3 ozs. This machine flew a horizontal distance of 368 feet, the air being quite calm.

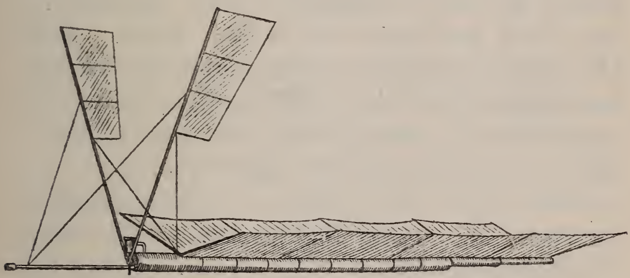


Fig. 15.—Hargrave's Machine Driven by Compressed Air.

Other models were also made, using compressed air as the motive power. One of larger size than the machine previously described, the length of the reservoir backbone being 6 ft. 11 ins. by 2 ins. diameter; capacity, 251 cubic ins.; weight, $15\frac{1}{2}$ ozs. Area of body plane is 3,074 square ins., of which 732 square ins. is in advance of the centre of gravity of the machine. The engine cylinder has a diameter of 2 ins., and the piston a stroke

1·28 ins.; weight of engine, 11 ozs.; length of wing, 31 ins.; area, 216 square ins. The reservoir was charged to a pressure of 250 lbs. per square in., which was reduced to 57 lbs. per square in. at the piston; its weight charged 59 ozs. An expenditure of 509 foot lbs. of work gave 46 double vibrations of the wings, carrying the machine through a flight of 512 feet.

Another engine was tried with this machine, the cylinder diameter being 2 ins.; stroke of piston, 1½ ins.; weight, 9 ozs.; pressure of air, 69 lbs. per square in. at the piston. With 54½ double vibrations of the wings the machine had a flight of 343 feet in 23 seconds, an estimated expenditure of energy being 742 foot lbs. for a speed of 10 miles per hour approximately.

Trials were made with a model propelled by means of a steam engine, and thrust results obtained as follows:—

2·2 vibrations of the wings per sec. gave a forward thrust of		...	...	·75 lbs.
2·3	Ditto	ditto ...	...	·9 ,,
2·4	Ditto	ditto ...	...	1·1 ,,
2·5	Ditto	ditto ...	...	1·25 ,,

There is no novel feature about the steam engine, but the boiler is made of 12 ft. of copper pipe, ¼ in. diameter, coiled into a tube of asbestos sheet. It weighs 20¼ ozs., including steam and water connections. Water is fed to the boiler by a feed pump $\frac{7}{32}$ in diameter from a triangular tank fixed underneath the body of the machine. Capacity of engine cylinder, 2·2 cubic ins.; water space in boiler, 2·8 cubic ins.; external surface of boiler, 113 square ins.; internal surface, 71 square ins. For fuel, vaporised methylated spirit mixed with air, the spirit being contained in a cylindrical tank fixed at the top of the boiler. When the engine was working at the rate of 182 double vibrations of the wings in 80 seconds, 6·9 cubic ins. of water were evaporated by 1·7 cubic ins. of spirit.

The total weight of the machine is 64·5 ozs., of which 12$\frac{3}{4}$ ozs. are for the strut and body plane. Spirit and water weighed 5 ozs., and the engine gave 0·169 H.-P. when driving the wings at 2·35 double vibrations per second. With 10 ozs. more spirit and water, Mr. Hargrave calculates that the machine would fly a horizontal distance of 1,640 yds. The boiler is empty at starting, and, first of all, is warmed by a Bunsen flame. The spirit tank is then heated until the vapour ignites the flame, being maintained by some asbestos put into the coil. As the boiler becomes red hot, the wings are vibrated for a few strokes; the pump discharges a small quantity of water into the boiler; steam is thus instantaneously generated on the flash principle, aud the engine commences to work.

A larger machine is designed to have 480 square ft. of horizontal plane, weight 260 lbs., requiring

3 H.-P. for propulsion, and to run for 10 minutes at a time.

Mr. Hargrave has regularly published accounts of his experiments in the Transactions of the Royal Society of New South Wales. The matter given in Vols. XVII., XIX., XXI., XXIII., and XXIV. goes extensively into the subject of mechanical flight by means of vibrating wings. The following comparison between two of his machines appears in Vol. XXIII., one of them being screw propelled, and the other having vibrating wings or trochoided planes, as he calls them.

	Screw.	Trochoided plane.
Total area in square inches ...	2090	2130
Square inch area per lb. weight ...	1045	1019
Weight in lbs. ...	2·00	2 09
Lbs. weight per square inch. ...	·00095	·00100
Foot lbs. of power used ...	196	470
Horizontal distance flown in feet ...	120	270
Distance in feet per foot lb. of power	·61	·57

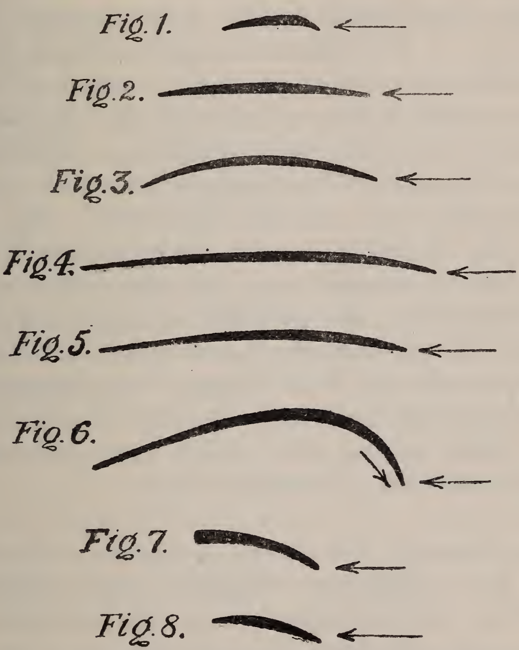
One of Mr. Hargrave's engines was made to serve as the boss of the screw propeller. It had three cylinders, ·88-in. bore, each being in line with one of the blades, and all in the same plane; weight, 7½ ozs.; stroke of pistons, 1·3 in.; working pressure of air, 150 lbs. per square in., falling to 120 lbs. per square in.; cut off at ¾ stroke;

speed, 456 revolutions per minute. The propeller blades were each of an area of 32·7 square ins., and set at an angle of 20 degs.; pitch, 44·4 ins.; diameter of propeller, 36½ ins.

The Hoffman flying machine models have been produced to imitate the flight of the stork. They are of aeroplane principle, motion being produced by a screw propeller having two pairs of blades placed so that one pair is behind the other. For starting purposes the machine stands upon hinged supports which automatically fold up to the body as soon as flight commences. One of these models has wings of 9 ft. span and weighs 7 lbs. The wings were also tried in the form of an aeroplane divided into several sections, but did not prove successful in this arrangement. Steam and carbon dioxide engines were used for the motive power. The framework weighed about one-sixth of the total weight of the entire machine.

Horatio Phillips.

An inventor who has displayed much ingenuity and engineering skill, in England, is Mr. Horatio Phillips, of Wealdstone, Harrow. He has tried his ideas by means of an experimental machine which is of a larger size than that which might be called a model though it has not sufficient power to fly with an aeronaut on board. It has actually risen by its own contained motive power to a height of several feet and through a horizontal flight of about 50 yards. The length of the body of the machine is 25 ft. by 3 ft. in width; the propelling arrangement is a screw 6 ft. 6 ins. diameter, driven by a compound steam engine, the boiler being carried with the engine upon the machine; and the area of propeller blade surface is 4½ square ft. A peculiar screen arrangement of aeroplanes is used for lifting and sustaining the machine in its flight. This looks like a common venetian window blind, but in fact it is the result of many years of experiment and thought, and is the embodiment of Mr. Phillips' ideas upon the question of flight by means of aeroplanes. The blades are not flat in section but concavo-convex, the curves being shaped accurately to a definite design based upon the results of experiments. The upper side of the blade is convex with the maximum curvature near the leading edge. The under side is concave, but with a small amount of convexity near the leading edge. Width of each blade is 1½ ins. only, and length 19 ft.; total size of entire frame, 19 ft. by 8 ft. in depth; sustaining and lifting surface equals 140 square ft. area. Each blade has a maximum thickness of one-eighth of an inch. The concave side is hollowed to a depth of one-sixteenth of an inch, they are made of wood, and fixed in a steel frame. When these blades are propelled in a horizontal direction they are really moving through a current of air, the velocity of which will depend upon the speed at which the blades are moved. The air current is deflected in an upward direction by contact with the forward edge and curves over towards the trailing edge, inducing a partial vacuum above the top surface of the blade. An air current also passes under the blade up into the concave under-surface, pro-



g. 16.—Shapes of Sustaining Blades tried by Phillips.

ducing a pressure against it. The result of the combined effects of pressure underneath and vacuum on the top causes the blade to rise and exert a lifting effort. This effect is produced by each individual blade; the combined effort of the whole number of blades fixed in the frame is the total lifting power of the machine. According to Mr. Phillips, he has produced a lifting effort by this means of nearly 3 lbs. per square foot of blade surface.

The experiments which have enabled Mr. Phillips to determine the most efficient form of blade were made by him on behalf of the Aeronautical Society of Great Britain. He placed a variety of shaped wood blades in a current of air, and measured the lifting power and thrust backwards by a suitable apparatus. Fig. 16 gives an idea of the various blade sections tried. In addition, an experiment was made with a wing of a rook dried and prepared, so that it could be placed in the apparatus and tested as a comparison with the wood shapes. An account of these experiments is to be found in *Engineering*, Vol. XL., August 14th, 1885, page 160, from which this table of results is taken.

Form.	Speed of air current.	Dimensions of blade.	Lift effort.	Backward thrust.
	feet per sec.	ins. ins.	ozs.	ozs.
Plane surface	39	16 x 5	9·0	2·0
Fig. 1	60	16 x 1·25	„	0·87
„ 2	48	16 x 3	„	0·87
„ 3	44	16 x 3	„	0·87
„ 4	44	16 x 5	„	0·87
„ 5	39	16 x 5	„	0·87
„ 6	27	16 x 5	„	2·25
Rook's wing	39	0·5 sq. ft. in area	8·0	1·0

The centre of effort of the surfaces was found to be one-third of the breadth from the forward end. The under surfaces of all the shapes are hollow, and to obtain the best efficiency from a given surface the amount of concavity and convexity must bear a certain definite proportion to the velocity of the air current.

The actual weight of the flying machine in working order was 360 lbs., and it carried a load of 56 lbs. in addition. In order that the flight could be controlled, the machine was attached to a pillar fixed in the ground, by wires, and the movement was in a circle of which the pillar was the centre. It was not allowed to rise more than about three feet from the ground, and was steadied by a wheel at the forward end of the body which travelled upon a circular track 628 feet in circumference, contact being maintained by a weight of about 17 lbs. pressing the wheel in a downward direction. The guide wheel was also connected by a wire to the central pillar. Speed of propeller about 600 revolutions per minute; the machine not only raising itself but a weight of 72 lbs. as well, under various conditions of wind. Apparently the sustaining blades give best results when they are horizontal. It seems that there is a best proportion of lifting surface to propelling power. The results obtained were not so good when the area of blades was increased without any increase of propelling power. Other particulars of a trial run are: Speed 40 miles per hour; weight of machine 330 lbs. It flew 1,000 feet without descending, and lifted a load of 55 lbs., the lifting planes thus sustaining 2½ lbs. (approx.) per square foot of under-surface area.

Ader.

From 1882 until 1892 Mr. Ader, a French electrician, has constructed in France some flying machines apparently intended for purposes of warfare. The first one of these weighed 53 lbs., and measured 26 feet across the wings, which

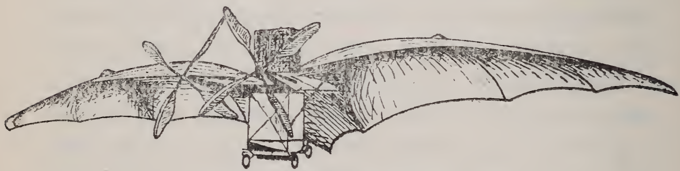


Fig. 17.—Ader's Machine.

worked with a vibrating movement by muscular power. A later model had wings of 54 feet measurement across. It weighed 1,100 lbs. and five years were spent upon its construction. The motor was contained within the body. Some amount of secrecy has been observed with regard to these machines and the experiments made with them, as the money for their construction and trials, to a sum of about £26,000, was provided by the Minister of War. The wings were made of silk, and though of jointed construction, did not vibrate, but served as aeroplanes, propulsion being effected by two screw propellers having four blades each, driven by a steam engine. This engine is said to be a triumph of mechanical work —four cylinder compound type, weight 70 lbs., and to have given 20 to 30 H.-P.; its parts being cut from solid forged steel. Supporting wheels are fitted to the body so that the machine can travel upon the ground whilst acquiring the necessary speed at which the aeroplane wings commence to produce a lifting effect. About 20 to 30 yards of level surface is required. According to Mr. Ader he was successful in making the machine fly several hundreds of yards, and to rise 50 or 60 feet into the air. Official trials were made at the camp of Satery, but the Minister of War does not seem to have considered them satisfactory, as no more money was provided, or the inventor did not prefer to continue. Parts of these machines are preserved in the museum of "Arts et Metiers" at Paris.

Sir Hiram S. Maxim.

Remarkable work has been done in England by the well-known engineer, Sir Hiram S. Maxim, who not only made many experiments with models but constructed a steam flying machine of such size that engines of 350 H.-P. were fitted to drive its screw propellers. Sir Hiram S. Maxim is an American by birth, and his earlier work was done in the United States, where he received a training in mechanical work. In the early days of electric lighting he was actively engaged in electrical work, inventing the Maxim incandescent lamp, the Maxim dynamo and regulator and arc lamps. The invention of his wonderful automatic machine gun made his name familiar all over the world.

It might well be anticipated that the inventor who could produce an invention requiring such skill, perseverance, and originality as that displayed in the design of the Maxim automatic machine gun would attack the problem of aerial navigation in an equally skilful and original manner. This has been the case. Sir Hiram Maxim, unlike some inventors of airships who attempt to produce a perfect machine at the first essay and which usually wrecks itself and kills its designer on the trial trip, has proceeded to acquire practical knowledge by means of captive machines, wisely declining to go up in the air on his machine until he can control it and know what it is going to do. After considering the question for a long time, he commenced his experiments in 1889 by testing the propelling power of screws in air, and the lifting power of aeroplanes adjusted to various angles, the apparatus being suspended at the end of an arm about 60 ft. in length, and which revolved in a circle at varying speeds up to 90 miles an hour. Having thus acquired a great deal of accurate information, he constructed a large steam-driven machine—a photo of which is given on Plate X—which shows the machine with all its aeroplanes fixed in position; in the background is the large building erected for housing and building it. This machine is a marvel of mechanical skill in combining strength, lightness, and power, and consists of a platform carrying a light framework of steel tubes and wire stays which support the aeroplanes and propelling machinery; the latter comprises two compound condensing steam engines each having two cranks and driving a screw propeller made of wood covered with varnished canvas. The propellers are nearly 18 ft. in diameter and 16 ft. pitch. They run at 350 to 400 revolutions per minute; each engine gives approximately 175 H.-P. and weighs only 300 lbs. Steam is suppled from a water tube boiler of similar pattern to those of Yarrow and Thornycroft; this boiler, with its wind cutter, is mounted on the platform, and can be clearly seen in the illustrations; the steam pressure is 200 lbs. to 320 lbs. per sq. in., and firing is by gasoline, burned in a large number of jets. Steam can be raised 100 lbs. in one minute. The weight of the entire machine is about 7,000 lbs.; the width across the aeroplanes is, roughly, 120 ft. The experiments with this machine were made by running it along a railway track laid in Baldwyn's Park, in Kent, where Sir Hiram Maxim at that time resided. Strong wood guard rails were fixed alongside the running rails throughout the entire length of the track, and were so situated that the machine could not rise more than a few inches from the ground. Friction rollers were provided on the platform and came into contact with the overhanging portion of the guard rail as soon as the aeroplanes lifted to the pre-arranged amount. The machine was supported on the running wheels by vertical springs, so that it could lift itself vertically through a short distance without the running wheels ever leaving the track ; each spring was connected to a recording dynamometer apparatus so that the amount of rise and lifting power could be ascertained. The speed was up to 40 miles per hour, and the machine was brought to rest at the end of the run by means of a series of weighted ropes stretched across the track, which passed over pulleys and had sufficient slack to allow the machines to be checked by their accumulated drag as they were each picked up in turn. On one occasion, when travelling at full speed, the lifting power of the aeroplanes was so great that the guard rail gave way on one side, the machine immediately slewed round breaking the guard rail on the other side, and would have gone up into the air, but Sir Hiram Maxim, who was on board with an assistant, immediately recognised that an accident had happened and shut off steam, the machine coming to the ground a short distance to one side of the track. There were no marks of the running wheels on the ground between the spot where the machine alighted and the track, which proved that Sir Hiram Maxim had really succeeded in making a flying machine which would lift itself from the ground by means of its self-contained dynamic energy alone. With a total of 363 H.-P. 150 are lost in the slip of the screw propellers, 80 are expended in merely driving the machine through the air, that is by reason of air friction, and 133 are effective in producing a lifting effort. A thrust of 2,100 lbs. is exerted by the screw propellers when the machine is prevented from moving and 2,000 lbs. when it is in flight. The aeroplanes have an angle of 7·25 deg. with the horizontal. The problem of aerial flight was not yet completely solved; it was necessary to ensure that the machine could be steered, and kept on an even keel. Experiments were commenced with model machines in a very ingenious manner. The models consisted of cigar-shaped bodies carrying aeroplanes and driven by screw propellers; the motive power being obtained from the energy stored up in a heavy flywheel pivoted in the body of the model and connected to the propeller. A high framework was erected, from the top of which the models commenced their flight which was observed, and the behaviour of the steering and balancing arrangements noted. The model was held at starting by a clip so that it could be instantaneously released, and the propeller engaged with a claw clutch which was spun up to speed by means of a heavy falling weight pulling on a cord which passed round multiplying wheels. As soon as the propeller and its flywheel were spun up to full speed, the model was released and made its flight. These experiments came to an end by the expiration of Sir Hiram Maxim's tenure of Baldwyn's Park, and the flying machine was dismantled.

The engines of this machine were made of thin sheet steel in almost every part, everything being hollow or ribbed; the propeller shafts were also of hollow steel tube, the flanged couplings were connected by a large number of very small bolts; the pistons were double-acting. One of these engines, together with one of the screw propellers, and the complete model of the flying machine shown on Plate X, is at the present time to be seen in the Machinery Gallery of the Victoria and Albert Museum, South Kensington; also the experimental machine used for determining the power of the recoil when making the first automatic Maxim gun.

Sir Hiram Maxim is now resuming his experiments, in the hope of producing a successful flying machine, but the enormous expense involved is a serious obstacle; his experiments at Baldwyn's Park, and the construction of the steam machine, cost him more than £20,000 of his own money.

A considerable amount of information regarding the details of the propelling machinery, with an illustration of the boiler, is given in *Engineering* for August 10th, 1894, Vol. LVIII., page 196, and in an earlier number for March 17th, 1893, page 226, Sir Hiram Maxim gives some of the figures of his trial runs with curves, showing the lifting effect produced by the aeroplanes. At a speed of 27 miles per hour, the indicators at the rear-supporting wheels recorded a lift of nearly 3,000 lbs., and those at the forward wheels more than 2,500 lbs.; the thrust exerted by the screw propellers was 700 lbs. Another diagram records a total lift of 6,500 lbs. at 27 miles per hour. The area of the main lifting plane is given as 2,894 square ft.; that of the small plane 126 square ft.; the area of the bottom of the machine,

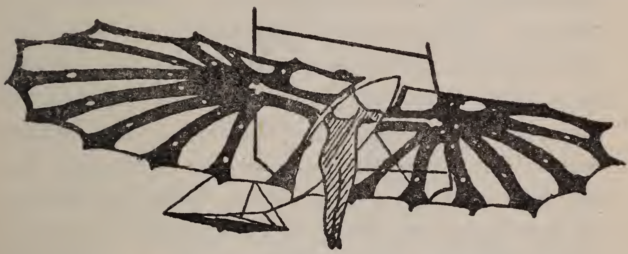


Fig. 18.—Pilcher's Soaring Wings.

140 square ft. A portion of the total lifting effect, amounting to 500 lbs., is stated to be due to a head wind, which thus assisted to raise the machine by its effort upon the aeroplanes; 600 lbs lifting effort was therefore due to the thrust exerted by the screw propellers. This thrust at full power was 1,960 lbs.

Percy S. Pilcher.

Mr. Percy S. Pilcher achieved some success in England with aeroplanes, his experiments extending over six years, during which he made trials with five different patterns. They were all of sufficient power to lift a man, and Mr. Pilcher made many ascents, in the end meeting with an accident which caused his death whilst trying the last model, No. 5, which had given best results. His aeroplanes (Fig. 18) were in the form of concave wings constructed with a cane framework, over which was stretched a material known as spinnaker silk. A smaller plane was fixed as a tail. The experimenter was fixed to the machine by his elbows. Motive power was produced by a horse moving upon the ground and pulling the machine by a rope, a losing purchase being provided to augment the velocity. At starting, the experimenter ran upon the ground, the aeroplanes lifting him as soon as the speed became sufficient. At this stage the lift would be continued and increased owing to the pull of the horse, which ran whilst the flight was in progress. When the experimenter desired to descend he released the rope attachment by means of a cord provided for this purpose, and soared to the ground by his own momentum. It was the intention of Mr. Pilcher to afterwards use an oil engine to provide the propelling power when perfecting his machine, but the fatal accident intervening put an end to the experiments.

Professor Langley.

An advocate of aeroplane machines is Professor Langley, of the United States of America. His apparatus, constructed in 1903, is capable of supporting a man, and has successfully flown a distance of three-quarters of a mile. The trials took place over the river Potomac, a high floating structure carrying the machine to favourable places for starting. From this elevated position at the top of the structure the machine was launched upon its flight. In case of accident it

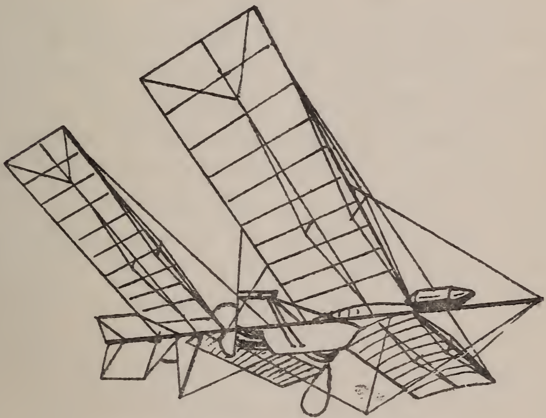


Fig. 19.—Professor Langley's Machine.

would fall upon the yielding surface of the water, and the wind would be more steady and less liable to eddies than if the experiments were conducted over a stretch of land. The material used for the construction of the frame parts is steel, and for the aeroplanes silk. Motive power is by means of screw propellers approximately 4 ft. in diameter, running at a speed of 1,000 revolutions per minute. The length of the machine is 15 ft.; its weight, 30 lbs.; its side planes are inclined at an angle of 135 degs. to each other; the plane at the rear is to act as a governor (Fig. 19).

Ernest Archdeacon.

Although not directly connected with flying machines the experiments of Mr. Ernest Archdeacon, the Aero Club of France, should prove interesting to workers in aerial navigation. To obtain definite data from the performance of air propellers, experiments were made with a motor cycle having an air propeller mounted in front of the handle bars and driven by a 6 H.-P. Buchet motor. (Plate XI). As shown on Plate XII, the transmission to the horizontal propeller shaft was through a flat belt. The propeller was made of aluminium and further lightened by being pierced with a number of small holes and the whole surface covered with gold beater's skin. The propeller measured 4 ft. 9 ins. diameter, and ran at 1,100 revolutions with an engine speed of 1,500 revolutions per minute. The weight of the machine complete is 70 kilogrammes (154 lbs.), and with the rider weighing 82 kilogrammes (180½ lbs.) the machine traversed one kilometre at the average speed of 49 miles per hour.

Further experiments have been made by the well-known authority, Captain Ferber, with the car illustrated on Plate XIII working on the same principles. The "Buchet" motor of this car develops 9 H.-P. and drives two propellers.

The air propellers have also been tried for the propulsion of boats (Plate XIV) and, with a 70 H.-P. engine, the inventor, M. Trolanini, claims to have obtained a speed of 43½ miles per hour.

Hugh Bastin.

Many men have essayed to obtain mechanical flight by following the wonderful principles evinced by Nature in both birds and insects. One of the more or less successful inventors in this field is Mr. Hugh Bastin, of Clapham, London, who, after many years of study and experiment, produced a really practical self-contained and self-propelled model of a heavier-than-air flying machine. The exact details of mechanism have not yet been divulged. However, some three years ago it was the writer's privilege to have a private view of the machine, to see it actually rise from the earth without extraneous aid of any kind.

Mr. Bastin's penchant for natural history helped him to a considerable extent in studying the flight of birds and insects. The ballooning principle, he averred, although not carried out by the strictly gas-bag method, is adopted by several species of unwinged creatures. It is utilised by spiders, caterpillars, etc., for enabling themselves to drift in an air current to fresh fields of operation.

Seed-bearing plants also use similar devices. In each case, however, a feather structure is provided for temporary use, to cause flotation in the air of the bodies which in themselves are heavier than air. The idea of the apparatus is perfectly fulfilled, because the final resting place is immaterial and the whole scheme fortuitous.

Convinced that the ballooning principle was lacking in utility where controlled locomotion was required, Mr. Bastin put the dirigible balloon entirely out of court. He considered that it was a useless study. Furthermore, he concluded that in the matter of fixed aeroplanes Nature gave no useful model to man, and that for controlled aerial navigation the adoption of the aeroplane was another case of misdirected energy and profitless expenditure. Nature, he said, from the time of its earliest efforts up to the present time, has used wings and wings only for transporting a heavy body in the air from a place of rest to any other predetermined place with its own volition, through currents of air varying in magnitude and direction.

The secret of the birds always had a charm for him, and, in deciding to follow Nature's plan, he first considered the structure of the wing as used by birds, insects, butterflies, and the like. There are, he says, wings of feathers, of membrane, wings articulated and wings not articulated; some fixed at right angles to the body, and others adapted for folding. In all cases the same principle of construction was apparent, viz., a rigid front and a flexible back. The front rigid bar is used as a central pivot for vibrating propeller, the springy back part bending to the angle to form the same.

The front bar A is pivoted at the shoulder B (see Fig. 20, a membranous wing) and is vibrated vertically. The flexible part C, in meeting the

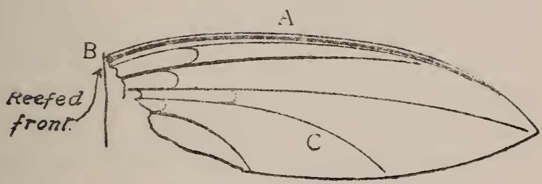


Fig. 20A.—Bastin's Machine—The Wings.

Fig. 20B.—Showing the various Amplitudes of the Beat.

air, is driven out of its plane both on the up and down motions (see Fig. 21), thus causing the air to press the wing or propeller forward. The direction of movement is at right angles to the direction of beat, and the body, of course, always forward. This happens whether the wing covering is of membrane or of feathers. Thus it will be seen that the wings are specially constructed propellers working on a well-known principle, so far as their direct action on the air is concerned, and form a truly perfect mechanical apparatus.

To operate these wings so as to obtain controlled flight requires other motions besides those described by the foregoing. The amplitude of the beat is varied by the bird according to the speed and direction intended. When the bird desires to turn, one wing may be given a greater beat. Normally, for a horizontal direction of travel the wings beat vertically; but the plane of the beat may be varied at will for upward or downward flight, the mechanical power being, as before shown, always applied in a direction at right angles to the direction of flight. The normal position of the wing when outspread, but not moving, is parallel to the horizontal plane, but for gliding upwards or downwards, using the wing as a pure aeroplane, this position may be changed, and the plane curved to suit the direction of flight required.

Mr. Bastin's machines have never progressed beyond the model stage, however. His work has been entirely satisfactory as far as it has gone, and the above statements as to the action of the wing seem to be borne out perfectly by the model. The first model was made before the advent of the petrol motor. It had a single pair of wings actuated by a very light but powerful steam engine. The weight of the boiler, the fuel, and water supply was too much for the machine, and, besides, was not at all convenient for the purpose. The present model is shown in the accompanying photograph (Plate XX), and is a much more practical machine. It has a double set of wings to

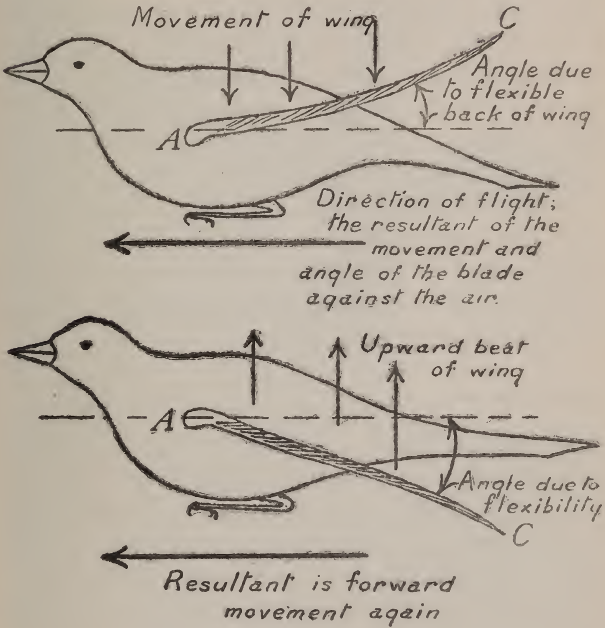


Fig. 21.—Bastin's Experiments.

Two diagrams showing the action of a bird's wing. A is the rigid front and C the outer edge of the flexible posterior portion of the wing.

give it better fore and aft stability, and has a small petrol engine for power supply. Each wing is attached to a trunnion, which can turn, and so alter the plane of the beat. Mechanism is also provided for altering the amplitude of the beat. The body of the model is 44 ins. long and 12 ins. in diameter, and the total spread of the wings from tip to tip is 84 ins. The writer, as already mentioned, was present at a private trial some three years ago, when, without external aid, the model, which is very weighty, scaling certainly not under 40 lbs., traversed the specially prepared "run," rising from the surface about half way along. The stopping of the engine (the operator pulling the string which trailed from the model) brought the machine heavily to the ground. Nothing but the risk of serious damage, and the lack of funds which would be required to make such damage good, has, it is understood, prevented a more extended trial of its powers.

Bleriot-Voisin.

The earlier Bleriot-Voisin Aeroplane with which experiments were made on Lake Enghein, consisted of two box aeroplanes of elliptical shape placed several feet apart and supported on the surface of the water by hollow floats. (Plate XV).

The total length of the "box planes" was 6 metres (19 ft. 8 ins.) and the width of the continuous surface $1\frac{1}{2}$ metres (4 ft. 11 ins.) The extremities and underside of the lower aeroplanes being more or less inefficient, the total lifting surface has been caluculated as 60 square metres (645·6 square feet).

The purpose of the arrangement was to obtain

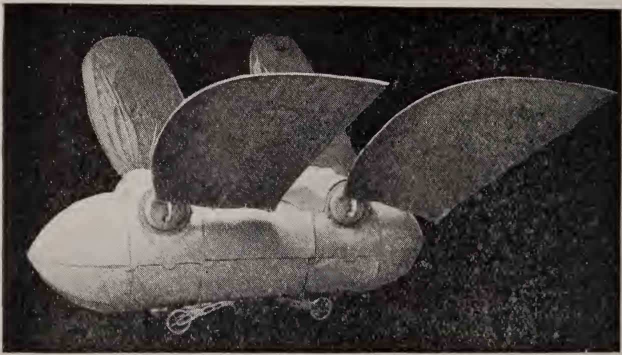
PLATE XVII.—The Santos Dumont Aeroplane "No. 14 bis."
A View of the Engine, with M. Santos Dumont in the Car.

Facing page 88.

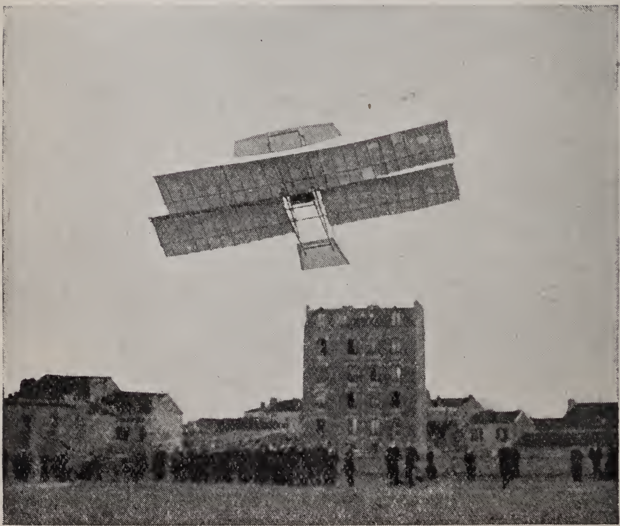
PLATE XVIII.—The La Vuia Machine.

PLATE XIX.—Gliding Experiments with an Archdeacon Aeroplane, "Letting Go."

PLATE XX.



Model of Mr. Bastin's Flying Machine.



Experiments with an Archdeacon Aeroplane.

definite data as to the lifting power and also experience in controlling the aeroplane in a relatively safe manner. No success, however, has been reported. Subsequently the leading elliptical box plane was discarded in favour of a pair of horizontal superimposed surfaces with a similar but smaller set of guide aeroplanes projecting out in front of all. This set was hinged horizontally so that it could be tipped up or down in the usual way.

For driving the arrangement a 24 H.-P. Antoinette petrol motor was employed. The motor actuated two wooden propellers running at 600 revolutions per minute.

A similar, if not the same, machine was fitted up on a suitable carriage to roll over the surface of the ground. When tried in Paris the machine did not rise in the air although a good speed was obtained. This was proved by the fact that when it came to a ditch it was not supporting itself in the air but fell into the rut in the ground and the carriage and framework were badly smashed.

Santos Dumont.

When it was reported, early in 1906, that M. Santos Dumont, the intrepid aeronaut whose work in connection with dirigible balloons has been summarised in the foregoing chapters, was giving up further efforts in that direction and was about to build a heavier than air machine, it was not generally thought that he would be so successful with the first machine of the new type.

The machine with which Santos Dumont obtained so large a measure of success in the fall of 1906, is shown in the accompanying photographs. "No. 14 *bis*" (Plate XVI), is constructed on the superposed aeroplane method, the two sets of aeroplanes being of cellular form and placed at a slight angle to the horizontal as shown. In front of the aeronaut's platform protudes a long "girder," at the end of which is a box rudder which can be moved on a horizontal axis from the platform and gives the machine a rising or falling movement.

The position of the engine will be seen in the photograph (Plate XVII). An Antoinette motor with eight inclined cylinders is used giving 50 H.-P. and driving an aluminium screw propeller, 6 ft. diameter, having 2 blades. The speed of the engine is 1,500 revolutions per minute. The span of the wings is 12 metres (39 ft. 4 ins.,) and the total lifting surface 80 square metres (860 square ft.) The weight of the machine, without the distinguished operator, is 160 kilogrammes (352 lbs.) The engine weighs only 72 kilogrammes which works out at 3·16 lbs. per H.-P. The experiments with this machine range from July to the end of the summer. The earlier trials at Bagatelle, Paris, Santos Dumont drove the machine across the field at a speed of 40 kilometres per hour ($24\frac{3}{4}$ miles per hour), with the propeller running at approximately 1,000 revolutions per minute, for over 100 metres. Towards the end of the run the aeronaut tipped the guide aeroplane slightly and the two front wheels of the carriage (it was then fitted with three wheels, as Plate XVII. rose off the ground first; then the rear wheel left terra firma and the machine soared for a distance of 16 to 20 feet. In striking the ground the machine was badly damaged.

Later, M. Santos Dumont accomplished free flight for fully 60 metres (nearly 200 feet,) at a height of 6 to 8 feet above the ground; Plate XVII showing him starting the ascent.

Several trials had been made during the day (October 23rd,) but about half past four, after some slight preparations had been made, he started off at about 25 miles per hour and soared the distance above mentioned. It appears that the aeronaut could have gone further but he became rather nervous, owing it is said to a slight rolling tendency and the presence of people ahead; he then cut off the ignition and the machine came to earth. It did not strike the ground heavily, only slightly buckling the carriage wheels.

Santos Dumont's machine is not provided with a rear vertical rudder and the rolling tendency may have something to do with this. As a result of the flight of October 23rd the Aero Club of France, although the distance was not accurately measured, awarded him the Archdeacon Cup, as there was no doubt that his "No. 14 *bis*" actually flew for more than the allotted distance of 25 metres (82 feet).

The brilliant success achieved with this machine has decided M. Santos Dumont to build another aeroplane, and he declares his intention to make the lifting surfaces of wood instead of canvas. Owing to the publicity of the grounds at Bagatelle, he will also conduct further experiments at St. Cyr, by permission of the military authorities.

In the new machine he proposes to use a single supporting wheel for the carriage and to increase the power to 100 H.-P., at same time reducing the width of the wings and therefore the supporting area.

Count de la Vaulx.

As already mentioned, Count de la Vaulx, the owner of the dirigible described on pages 47 and 48, about the time of M. Santos Dumont's brilliant achievement with his "No. 14 *bis*" became converted to the aeroplane as the better device for solving the problem of aerial flight. In pursuance of this new idea he is at the present time building, in conjunction with Messrs. Tatin and Maurice Mallet, at the latter's establishment in Paris, an aeroplane on the plan shown in Fig. 22.

As will be seen, the machine differs in most of its attributes to the box aeroplane of Santos Dumont. It is to have large outspread planes like the wings of a bird. Two propellers *(s)* are to be used, which will rotate in opposite directions, and be driven by a 50 H.-P. Antoinette motor, as specially made for aerial purposes.

The car containing the mechanism forms the body of the machine and is below the centre plane AP. The lateral aeroplanes AP^1 and AP^2 are continued outwards from the centre plane.

Behind, at some distance from the car, will be fixed the aeroplane forming the tail (T), hinged to which will be the horizontal rudder H. The vertical rudder (R), which will be used to control the lateral movement of the machine, is to be

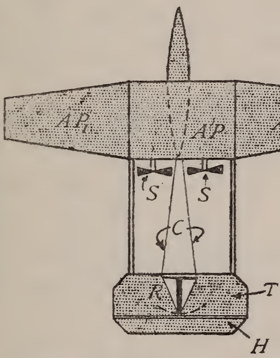


Fig. 22.—A Plan of the New de la Vaulx Aeroplane.

placed below the tail and worked by cords C from the nacelle.

The designers are endeavouring in this machine to reduce the ineffective surfaces to a minimum, with a view to obtaining a higher speed and greater lifting capacity with a lower expenditure of motive power than that which has been heretofore accomplished. The only objection that may be raised to this desire is the fact that it may, for the present at all events, be better to sacrifice efficiency for the sake of stability and strength, and, when some degree of success has been obtained, to then turn every attention to the modification of those details which will result in obtaining an increased mechanical efficiency from the machine as a whole.

Vuia.

M. Vuia towards the end of 1906 carried out some experiments at Bagatelle, in France, with the machine shown in the photograph. (Plate XVIII). The device is fitted with two wide-spreading horizontal wings operated by a carbonic acid motor, and, for the purpose of increasing the speed of the machine, a two-bladed propeller is mounted in the front. Slight accidents prevented any satisfactory results being obtained, but the inventor anticipates that he will be able to leave the ground and fly for a longer distance than that at the time had been covered by M. Santos Dumont with his "14 *bis*."

Orville and Wilbur Wright.

For some time past reports have reached England of wonderful successes obtained by the brothers Orville and Wilbur Wright, of Dayton, Ohio, U.S.A., with an aeroplane machine. The earlier experiments of these inventors were restricted to glides with controllable aeroplanes (Fig. 23) which carried the operator and were started from eminences.

With a motor-driven aeroplane, of which our sketch is said to be a true representation, weighing 925 lbs., Messrs. Wright claim the following successes :—

1905.						
Sept.	26.—$11\frac{1}{8}$	miles' flight in	18	mins.	9	secs.
,,	29.—12	,, ,,	19	,,	55	,,
,,	30.—12	,, ,,	17	,,	15	,,
Oct.	3.—$15\frac{1}{4}$	,, ,,	25	,,	5	,,
,,	4.—$20\frac{3}{4}$	,, ,,	33	,,	17	,,
,,	5.—$24\frac{1}{5}$	,, ,,	38	,,	3	,,

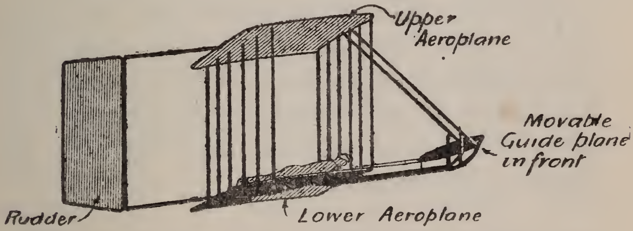


Fig. 23.—A diagram of the Wright Gliding Aeroplane.

Mr. Chanute, a well-known authority, also independently reports that he witnessed a flight of 1,377 feet in $23\frac{4}{5}$ seconds in 1904, the conditions prevailing being a wind running at about six miles per hour. After having travelled about 500 feet, a gust of wind struck the aeroplane, tilting it in the air, and Mr. Orville Wright, not being able to preserve the equilibrium, alighted by running with the wind instead of against it as was usual. The machine was slightly damaged.

A leading French automobile journal sent a representative to America to investigate the claims of the brothers Wright ; but the machine had at that time been taken to pieces for alterations. Full details of the apparatus are not to hand owing, it is said, to the desire for secrecy on the part of the experimenters. More recent reports say that they are engaged upon a new machine with a lighter engine, but during 1906 no further records have been made.

Reviewing the various statements appearing in the press and elsewhere, one feels almost obliged to pass over the work of the Wright brothers in favour of the well-authenticated and remarkable performances of M. Santos Dumont in Paris, more particularly as full details of the machine with which the records claimed were made do not appear to be forthcoming.

T. W. Clarke.

During the past year or so experiments have been made with aeroplanes, built after the pattern of those used by Messrs. Wright, by several well-known aeronauts in France and England. Mr. T. W. Clarke, A.M.I.C.E., tried a machine at Aldershot in which the top aeroplane (or "aerocurve," the surfaces being curved with the concave side underneath) was longer than the lower one, and the tail consisted of two vertical planes with horizontal surfaces projecting outwards therefrom near to the top. The trials were made with the aeroplane used as a kite with three guy ropes. During the time Mr. Clarke was up in the machine the two side guy ropes were never more than slacked off, and naturally nothing but a certain amount of experience in handling the machine seems to have been gained. The main aeroplanes were 39 ft. and 31 ft. long by 63 ins. wide, with the front horizontal guide plane and the vertical rudders being each about 10 ft. fore and aft of the main surfaces.

Archdeacon.

M. Archdeacon, the well-known aeronaut of Paris, built an aeroplane of the Wright pattern, specially designed for gliding experiments, in 1903-4. The general construction of the machine will be gathered from the photographs on Plates XIX and XX. It had the forward movable plane to control the vertical movements and the usual rudder at the rear. When tried at Merlimont sand-dunes the glides did not exceed 25 metres (82 ft.) in length, and considerable trouble was experienced in drilling the attendants. It was found that they had to let go all at the same moment, otherwise the experiment failed. M. Archdeacon also carried out some trials with aeroplanes supported on the surface of the water in a similar manner to that adopted by M. Bleriot on Lake Enghein. No motive power, however, was provided on the aeroplane, but the machine was towed along by a motor boat as shown in the photograph (Plate XXI).

Bellamy.

Mons. Bellamy, who has declared his intention to compete for the *Daily Mail* prize, has recently been engaged upon stability trials with an aeroplane supported from a captive balloon. The apparatus consists of a pair of double-decked aeroplanes. Beside the horizontal rudder or guide plane forward, and the vertical rudder in the rear aeroplane, a pair of triangular "sails," placed at an angle, are fixed between the two sets of aeroplanes. The front planes measure 32 ft. 10 ins. by 9 ft. wide, the rear planes being of the same width but only 23 ft. long. The two sets are placed 33 ft. apart. A 50 H.-P. engine, driving the propellers by chains, is employed. Mons. Bellamy claims to have already obtained free flight for several hundred yards, but although he says he can control the height of the machine from the ground, the turning or lateral steering of the machine is a problem he has yet to solve.

Henri Kapfera.

Henri Kapfera has designed an aeroplane, which is shown on Plate XXII, having a breadth of 11 metres (36 ft.) across the upper plane and 10 metres (32·8ft.) across the lower plane, the length of the surface is 1½ metres (4·92 ft.) in each case, A double horizontal rudder is placed in front, being connected to the body of the machine by an enclosed girder which tapers to a point in the forward direction. Two smaller aeroplanes, one above the other, are fixed at the rear, each four metres (13 ft.) in breadth by 1½ metres in length ; vertical screens divide them into two rectangular parts as shown in the photograph. It is driven by a 24 H.-P. Buchet Motor, and a two-bladed propeller. Total aeroplane surface is 42 square metres (452 square feet). According to accounts of this machine, the rear aeroplanes are supposed to increase the horizontal stability, and the motive power is to be increased to 50 H.-P. When starting the machine runs upon the wheels shown in the photograph to obtain initial speed.

Dufuax.

Many inventors have pinned their faith to the horizontal-running screw propeller as a means of overcoming the force of gravity. There appears some doubt, however, as to whether or no the lifting power of these screws would be more or less destroyed when the propelling screws are brought into action and the machine is made to travel in a horizontal direction. Then there is the question of the efficiency of screw propellers for lifting purposes.

With regard to the latter point, Mons. Dufuax demonstrated at St. Cloud, in 1905, with a machine consisting of a tubular frame work 16 ft. long, having a pair of propellers revolving in opposite directions at each end of the machine. A 3 H.-P. petrol motor was employed and the total weight lifted was 51 lbs., which is 17 lbs. per unit H.-P. A comparison of the power required for this machine may be made with the results obtained by the use of aeroplanes (see pages 67 to 72.

Vuia and Alvarez.

This machine somewhat resembles that tried at Hendon in 1904, by Senor Alvarez, of Brazil. The latter was a "winged" aeroplane which was provided with two propellers and a vertical tail rudder. When tried it had no passenger aboard but was dropped by an automatic device from a balloon at an altitude of 3,000 ft. The wings were 40 ft. from tip to tip and the weight of the machine 150 lbs. When released it made a dive earthwards but the rudders righted it and, on an even keel, it glided for about a mile, coming to rest without appreciable damage. The motor was only a 2 H.-P. one and worked the two 5 ft. propellers at about 175 revolutions per minute.

Hutchinson, Frost, and D'Esterre.

In considering the application of the methods by which birds and insects fly through the air, we must not forget the experiments of Dr. Hutchinson and Messrs. E. P. Frost and D'Esterre with winged machines.

In his earlier experiments Mr. Frost was not able to prove his theories, owing to the defects in the mechanism supplying the motive power. Later, however, these gentlemen were successful with an apparatus using goose wings. The "model" was slung on the end of a balanced pole, the end of which, after the manner of the Phillip's device, could travel in a circular path through the air with very little resistance.

The two wings had a total area of 3 square ft., and were flapped in synchronism by a small electro motor. The apparatus was slung from a spring balance attached to the end of the pole.

On experiment there was a good deal of movement due to the reaction of the beat of the wings on the body. However, there was a distinct forward movement owing to the flexion of the posterior portions of the wings. This vertical oscillation, however, was successfully damped by means of a tail and a steadier flight obtained.

The flaps were made at about 300 to 400 per minute and, with the one-tenth H.-P. motor used a maximum lift of 5 lbs. was obtained. The weight of the apparatus was 27 lbs. and the maximum forward speed obtained was approximately 5 miles per hour.

A larger apparatus was afterwards made, the wings and mechanism being mounted on a frame running on bicycle wheels. The wings were artificial structures and provided a total area of 60 square ft. and an outspread of 20 ft. The total weight of the machine was 232 lbs.

A 3 H.-P. petrol motor was employed to drive the wings, and to store up energy on the up stroke of the wings, elastic bands were used to give out their potential energy during every downward flap. In this way the load on the engine was rendered more constant. The frame was provided with devices to show the lifting power and forward movements of the machine, and at about 100 flaps per minute the whole arrangement was lifted 2 ft. off its special track.

From the information published by Dr. Hutchinson, he not only agrees that the flexion of the posterior portion of the wing gives a forward movement (at right angles to the direction of the beat, see Figs. 20A and 21), but he contends that the structure of the bird's wing provides for a valvular action, the air passing through the feathers on the upward stroke. That is, the wing is so made and shaped that it encounters a greater resistance on the down stroke than on the up.

CHAPTER IV.

THE ART OF FLYING.

IF the designer and maker of a machine intended to navigate the air was at one time certain to be looked upon as at least to some extent wanting in mental balance, the person who actually tried to fly with such an apparatus was decidedly regarded as being hopelessly mad. At the present day an experimenter can point to the names of such men as Chanute, Langley, Lilienthal, Maxim, Pilcher, and Santos Dumont, men of scientific mind, engineering ability, and intelligence of a very high order. Their experiments are examples of sound, logical reasoning, conducted with great care; and though two of them unhappily met with fatal accidents whilst practising the art of flying, they had foreseen that such results would occur under certain conditions, and were taking a reasonable risk. The fact remains that these men have made many experimental flights with safety, and those who follow will be not only justified but wise in giving careful consideration to the methods adopted by preceding exponents of man flight. Sir Hiram Maxim, as the account of his work on record shows, could have flown up into the air upon his machine, but, as he had not solved the question of maintaining equilibrium and steering, he prevented it from rising beyond a certain limited amount. In this way he was able to make trial flights with absolute safety and to acquire a considerable amount of information. Horatio Phillips, with confidence in his ideas based upon much accurate experimental work, preferred to confine his machine to a limited amount of rise, so that he could observe its action with safety. Yet more recently M. Santos Dumont, intrepid as he is, acted with extreme caution when he took his remarkable flight upon the "No. 14 *bis*" machine.

Otto Lilienthal practised so much with his soaring wing apparatus that he came to regard his trials as a sport, and it may be that this idea may actually come to be an existing fact. It is a question of perfecting the means and acquiring the art. The primary thing to do is to keep near to the ground, no matter whether the flight is made by means of a machine propelled by engine power or with supporting planes lifting by virtue of the soaring or gliding principle. The experience gained will not necessarily enable the person to take flights of high altitude. Lilienthal, however, considered that soaring and flying near the ground is much more difficult than at high altitudes, because the wind frequently moves in eddies, due to the hollows and elevations of the earth's surface. Santos Dumont advises the aeronaut to keep close to the earth, he does not regard the airship as in its place at great heights.

Airships or flying machines of even modest size propelled by engine power are very costly things to build and try if they are to lift the experimenter from the ground. Soaring apparatus, however, is comparatively cheap to construct and try. Mr. Hargraves has also shown that excellent flying models can be made at trifling expense, and he lays much stress upon this point in the accounts which he gives of his work to the New South Wales Royal Society. Wood, elastic, canvas, whalebone, cord, tin cans, and wire for engine cylinders and gear appear to be the kind of materials which are required, together with a very moderate equipment of tools. He proceeded with the idea that every model was of some value. Though it had not been a success in flying, it would be a record of experiment.

Lilienthal advises experimenters practising with soaring apparatus attached to the body to make trials with small wings at first and only in moderate winds. He says that when soaring with only 86 square ft. of sustaining wing surface he was tossed up into the air upon several occasions. This wing area had previously been 107 square ft., but had been reduced by trials. He advises that the flyer can release himself at once from the apparatus in case of need; that is, if he finds the wind taking control and the wings about to be thrown upwards in a dangerous manner, he can let go and save himself from a disaster. It is also not safe to make trials if the wind has a velocity of over 23 miles per hour unless sufficient skill in soaring has been attained by practice. In his account he says: "I never make the spread of wing greater than 23 ft., so that I can restore equilibrium by a simple change of centre of gravity." The wing breadth should be limited, so that this transfer of centre of gravity can be instantly effected so far backwards and forwards as to meet the action of the supporting air resistance to the limit of its movement. It should not be more than 8·2 ft., and will give a total area of 151 square ft., sufficient to sustain the weight of an average man; the weight of these wings will be 44 lbs. approximately.

In making a flight, the experimenter should not merely trust himself, like an inert thing, to the caprice of the wind, but try to exert a dominating and intelligent influence to control his apparatus. For example, if one wing is rising by the effect of the air current, he should move his legs towards it and keep it down. The natural tendency would be to allow the legs to hang towards the falling wing; but this is just the wrong action, as it would contribute to upsetting the equilibrium of the apparatus. To quote Lilienthal: "It does not take very long before it is quite a matter of indifference whether we are gliding along 6 feet or 65 feet above the ground; we feel how safely the air is carrying us." "Soon we pass over ravines as high as houses, and sail for several hundred metres through the air without any danger, parrying the force of the wind at every movement."

Mr. Pilcher leaves the following advice in the use of aeroplanes: "Keep the position of the aeroplanes low, not much higher than the common centre of gravity. If they are placed high, the tendency is for them to tilt the machine. The changes of the wind will act more quickly upon the aeroplanes than upon the heavier body.

In the United States, Mr. A. Chanute, an engineer, has given a great deal of attention to soaring machines. He appears to favour aeroplane wings placed over one another, and gives them the adjusting movement instead of moving the body of the experimenter like Lilienthal and Pilcher. His assistants have carried out some thousand trial flights under his direction without accident. The proportions of wing-sustaining surface used are ¾ square foot per pound weight; speed of flight, 22 miles per hour; calculated sustaining effort, 89 lbs. per horse-power effort of the wind and gravity. Mr. Chanute, in an illustrated account given in *Cassier's Magazine* for June, 1901, states the underlying principle of maintaining equilibrium in the air to be this: that the centre of pressure shall at all times be upon the same vertical line as the centre of gravity, due to the weight of the apparatus. In calm air this is fairly secure, but in a wind the centre of pressure is constantly moved.

The centre of gravity may be shifted backwards and forwards to coincide again with the vertical line passing through the new centre of pressure. Lilienthal and Pilcher accomplished this by adjusting their personal weight to new positions as required at the moment. As an alternative, the centre of pressure may be adjusted into a vertical line with a fixed centre of gravity by altering the angle of incidence or by shifting the position of the sustaining surfaces. These latter methods have been tried by Chanute in three different ways: 1. By fixing a horizontal tail (Penaud pattern) at an angle to the sustaining surfaces. This strikes the air with its upper or lower surface, alters the angle of incidence of the wings, and therefore alters the centre of pressure. 2. The wings pivoted at their roots, so that they can move horizontally. The arrangement is such that the impinging air shall automatically alter the angle of incidence and therefore adjust the centre of pressure. 3. The surfaces hinged so as to rock in a vertical direction, and arranged so that the impinging air automatically shifts the angle of incidence, and by this will adjust the centre of pressure. The last method is believed to be preferable; but Mr. Chanute says that one cannot be sure, as all the adjustments are very delicate. In his opinion the important condition is that the man shall remain staionary, and it will be advisable to make use of about one square foot of sustaining surface per pound to be lifted until the problem of maintaining equilibrium is solved.

This means speeds of about 20 to 25 miles per hour to make for safety when reaching the ground.

Mr. C. E. Duryea proposes that safety in experiments with large flying machines shall be promoted by suspending them, during the preliminary trials, from captive balloons.

Mr. L. P. Mouillard makes some rational remarks entitled "A Programme for Safe Experimenting." He also advocates the acquirement of skill, as in swimming, cycling, and so on, and says that the one great element of success is to take no chances of accidents. The problem will be solved by a timid man, almost a coward, but one who is also reflective and ingenious, who will accumulate in his favour all the elements of success, and eliminate carefully every element of accident (Proceedings of the International Conference on Aerial Navigation, 1893). Lilienthal states that he found the management of his apparatus become very difficult when the wind velocity exceeded 11 to 13 miles per hour, and advises experimenters not to leave the ground until they have become expert. He also always faced the wind so as to obtain better control. This means the equivalent of the well-known caution to would-be swimmers, "Don't go into deep water until you can swim." If you are practising to fly, don't let the wings take you up upon the wind more than a few feet from the ground until you have the necessary skill to manage the apparatus and adjust it to the varying velocities and directions of the air currents. Most certainly don't take your wings up to a height and launch out into the air as a preliminary trip.

CHAPTER V.

Flying Machines of the Future.

Like other appliances, flying machines will in their design, construction, and use follow a course of development. Those which achieve the first real success and are put to some useful purpose will seem clumsy and inefficient to the designers of machines at a time when, say, 50 years of progress and use have passed. Compare a modern bicycle with those made 30 years ago, and note the improvement in design and construction. A story has been told of an English engineer, a bicycle rider, who went to reside in the East during the early cycle days. Missing his favourite recreation, he decided to try and make a bicycle, even if a crude one, so that he could have some rides. The native mechanic, however, to whom he explained his design, absolutely refused to have anything to do with it. A machine with three wheels or four wheels he would make, but one having two wheels placed one behind the other was the idea of a madman. It would not keep upright, and he would not waste his time upon such a thing. The ancient Briton, when he launched his boat upon the water, probably regarded it as about the limit of naval architecture, yet from the same shores the thing which is called an Atlantic liner to-day carries passengers by the thousand to shores unknown to those early navigators. From the primitive boat to the modern steamship, how many successive improvements in design and construction exist! Can we say finality is reached?

The reasonable way to try and form some idea of what future flying machines will be like is to consider the results already obtained and the opinions expressed by those who have made experiments bearing upon the subject. In both of the principles available, namely, that of buoyancy, as exemplified by balloons and that of machines heavier than air, as exemplified by aeroplanes, a great deal of work has been accomplished, and each is still faced with difficulties. The exponents of either type can advance arguments to show that the other is impracticable. Sir Hiram Maxim has stated that it is not possible to construct a balloon strong enough to stand a speed of 15 miles per hour against a wind, as it would be forced out of shape and torn to pieces. But has the art of balloon construction reached finality? Count Zepperlin endeavoured to maintain the shape of his balloon by the use of an enveloping framework which enclosed the balloon proper, and which was in its turn surrounded by an envelope sufficiently large to leave an air space between. The resistance to the balloon offered by the opposing air increases enormously as the speed is increased. Double the speed does not mean double the re-

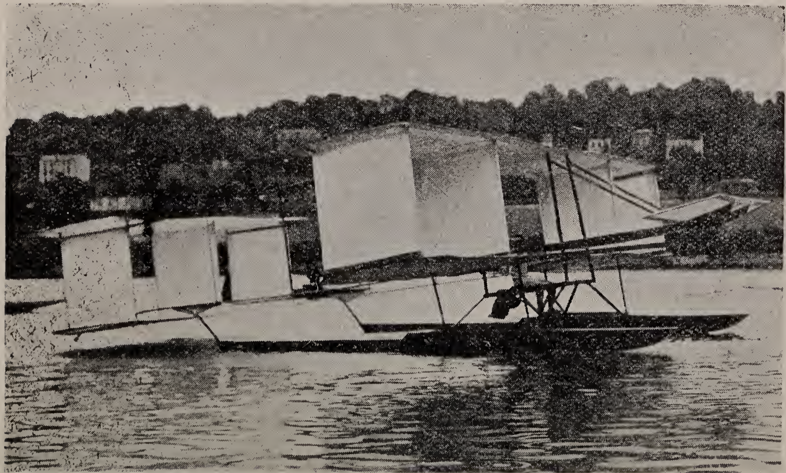


PLATE XXI.—Experimenting with Aeroplanes supported on the surface of the water and towed by a motor boat

Facing page 112.

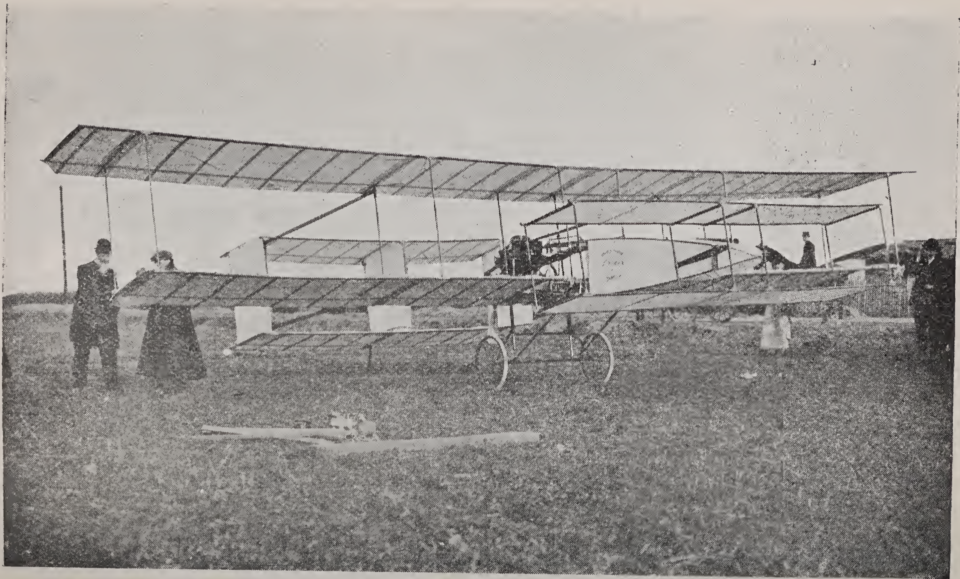


PLATE XXII.—The Kapferer Aeroplane.

sistance, but a great deal more; in fact it increases as the cube of the speed. It is, therefore, of great importance to shape the balloon so that it will offer a minimum amount of resistance to the air. According to Chanute, it can be reduced to 12 per cent. of that which would be offered by a disc having a diameter equal to that of the largest cross section of the balloon. Some experts agree that a speed of about 44 miles per hour is possible.

With regard to aeroplanes, Sir Hiram Maxim obtained a lift 18 times as great as the drift with small wood planes, but found the efficiency decreased when he made large planes of a flexible material. A wood plane will carry more than 100 lbs. of weight per horse-power used to drive it, but the large planes made of flexible material stretched upon a frame did not carry more than 40 lbs. per horse-power. Professor Langley obtained a similar kind of result, his small planes made of wood or metal lifting a greater weight for the driving power expended than large planes made of stretched paper. The loss of lifting power seems to be due to the less rigid surface not retaining its shape. Therefore aeroplanes, to give the best obtainable lifting efficiency, should be inflexible. In his experiments with small sizes and weights, Langley's aeroplanes propelled by screws carried at the rate of 250 lbs. per horse-power. The real weight used was only a few pounds, so that, according to the preceding statements, this efficiency would not be maintained with large planes unless they could be made of some absolutely rigid material. Regarding weight lifted per unit of area, according to Maxim more than 3 lbs. can be lifted per square foot of surface if well designed, his planes having a width of 13 ins. and length of 6 ft. carried 8 lbs. per square foot of surface. He also finds that when a large flat plane is used the whole surface does not do equal work. Most of the lifting is done by the forward portion, and the plane must be curved to an increasing angle if each part of the surface is to do a fair share of the work, again increasing the amount of driving power required. When several aeroplanes are used one behind the other a similar result takes place—the leading plane does the greater part of the work, for the reason that it works in air which has not been disturbed.

Lilienthal believed flat aeroplanes offered undue resistance, and determined that it is necessary to make the surfaces of concavo-convex shape based upon those of the wings of birds. Phillips's experiments led to the conclusion that flat or nearly flat surfaces were unsuitable (he says useless) for carrying heavy loads in the air. If flight is to be possible, he finds that each square foot of sustaining surface will have to be capable of supporting a weight of at least 3 lbs. If the sustaining area approaches a proportion of one pound carried per square foot, such a machine would not have sufficient strength, and be liable to damage from strong winds when at rest upon the ground.

Phillips maintained that no flat aeroplane would support 3 lbs. per square foot if driven at a practicable speed and angle of inclination. With his system of curved planes he claimed that 8 lbs. per square foot was lifted at 40 miles per hour horizontal speed. The proportion of lift to thrust was constant, and the weight of the aeroplane is not included. According to his experiments, a propelling thrust of about 100 lbs. would be necessary to support 1,000 lbs. in air; this multiplied by 39 ft. per second (according to him) as the lowest practicable speed will show about seven horse-power required. He says to double the speed at least twice the power and nearly twice the weight of propelling engine (steam) would be necessary. Including water in the boiler, he allows 60 lbs. for each effective horse-power developed. Mr. Hargrave in his communications to the Royal Society of New South Wales, however, warns experimenters against placing too much reliance upon thrust diagrams. He gives an instance of an experiment with one of his model machines which was driven by compressed air, the engine having three cylinders, 1½-in. diameter, ·79-in. stroke, cut-off at ¾ stroke; air pressure, 170 lbs. per square inch; weight of engine and screw, 6½ ozs. When the blades of the screw propeller were set at a pitch angle of 20 degs. a high thrust was obtained on the indicator, but the machine flew a very short distance. When the blades were set at an angle of 45 degs. a low thrust was indicated, but the machine flew 50 per cent. further. He reasons from this that the blades should be set parallel to the shaft and the pitch allowed to be automatically adjusted by torsion, the blade surfaces being placed entirely behind the supporting arms, but says that it is matter for consideration for those who prefer the screw propeller to flapping wings. This shows that there is still much to be discovered with regard to the behaviour of surfaces in motion through the air. According to one account of Langley's experiments with aeroplanes moved horizontally through the air at the end of a rotating arm, the propelling power required to move the plane decreased as the velocity increased. Under the initials J. H. K. a writer in *Engineering*, June 13, 1890, gives an account of some trials made with lifting screens in air. It is stated that one horse-power will lift 33 to 35 lbs., and the opinion is given that the power required when the machine is under weigh will be much less than generally supposed. Further, that to support a body in air, the quantity of air per second which moves under it should be equal in weight to that of the body as drawn down by gravity. But Mr. Henry Wilde, F.R.S., in the same journal also states that the results of some experiments made by him on the ascensional power of aerial screws did not give sufficiently promising results to induce him to proceed far in this direction. Screws working in air are really aeroplanes, whether applied for the purpose of propulsion in a horizontal direction or lifting in a vertical direction. Various experimenters have shown that such screws should, if properly designed, give efficient results as with screws correctly designed and working in water. Mr. W. G. Walker, A.M.I.C.E., made a number of trials with large air propellers in the latter part of 1899 to determine the thrust or lifting power obtainable per horse-power applied to rotate them. His results were issued as a report to the Royal Society of Great Britain, and an account will be found in *Engineering* of February 16, 1900. The propellers were 30 ft. in diameter, and consisted of canvas stretched upon a lattice frame. They were rotated at various speeds up to 60 revolutions per minute. Five were tried: A having four blades, each 6 ft. wide, placed as shown in the accompanying sketch, giving 350 square ft. area; B having two blades of same width as A, giving 175 square ft. of area, the two rear blades being removed; C had four blades as A, but they were each only 3 ft. in width, giving an area of 175 square ft.; D also had four blades each 3 ft. in width and placed as A, but with 6 ft. radial length nearest the centre removed from each blade, leaving four tips 9 ft. in length, giving an area of 103 square ft.; E was the same as A, except that the angle of the blades was 21 degs. to the plane of rotation instead of 12½ degs., the inclination of the others. The general results of the experiments show that the thrust varies as the square of the revolutions; the horse-power required to drive them varies as the cube of the revolutions; the thrust per horse-power varies inversely as the revolutions. For a given indicated horse-power propeller E gave the greatest thrust; at 16 indicated horse-power the thrust was 260 lbs.; A and C, 212 lbs.; D, 192 lbs.; B, 132 lbs. respectively. At the same number of revolutions A gave about double the thrust of B. For equal tip speeds the thrust per horse-power for propellers C and E were nearly equal; B was the least efficient. The thrust of B and E at a speed of 50 revolutions per minute was 9·4 lbs. and 15 lbs. respectively; E required 18·7 indicated horse-power. The framework was tried alone, and required 7·8 indicated horse-power.

From these experiments it appears that for aeronautical purposes screw propellers will give improved results, if made with a series of blades placed tandem fashion (Fig. 24), or that there is no disadvantage in placing them in this way, provided the resulting construction does not involve increased framework losses. As such large screw propellers really approximate to aeroplanes driven in a straight direction, this result is confirmed by the practice of experimenters, such as Chanute and Wright, who have come to use two or more aeroplanes superposed in preference to extending the surface area in one plane. Narrow blades seem to be as efficient as wide ones within limits, and the portion near to the centre does not add much to the thrust. It is important to design the supports to the blades, so that they will offer a small resistance to the air, or a large proportion of the driving power will be wasted. The power mentioned is that indicated at the cylinder of the

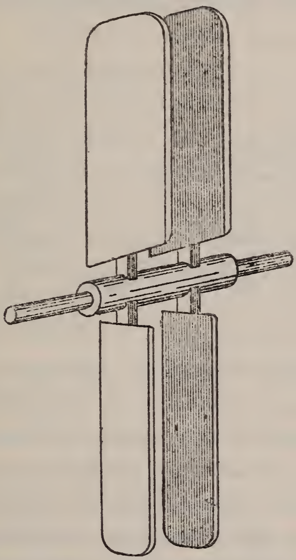


Fig. 24.—Air Propeller with Tandem Blades.

steam engine used to drive the propellers, and it therefore does not represent the actual power applied to the propeller shaft, a certain amount would be lost in overcoming the friction of the engine parts, driving belt, etc.

Hargrave in his experiments did not observe any tendency of the flying model to list by reason of the effort of the body of the machine to rotate on the screw propeller shaft. He concludes that for propelling purposes the screw and vibrating wing, or trochoided plane as he calls it, are about equally effective. Comparison may be made between the two by the following table of results given by him.

	Screw.	Trochoided plane.
Total area in square inches	2090	2130
Square inch area per lb. weight ...	1045	1019
Weigh in pounds	2.00	2.09
Pounds weight per square inch	.00095	.00100
Power used in foot pounds	196	470
Horizontal distance flown in feet ...	120	270
Distance flown in feet per foot pound of power...	.61	.57

Screw propeller was 28ins. diameter, two blades 7ft. 6ins. pitch, each 6 ins. in length, 6 ins. wide at the tips, and 3 ins. wide at the inner ends, giving a total surface area of 126 square ins. In his account he states that a feature of the machine is the small amount of thrust required to move a comparatively heavy body horizontally through the air when it is supported by a large flat surface. Apparently large area of surface is of more importance than a powerful propelling engine when speed is a secondary consideration. The successful models maintained a horizontal position, the body plane kept practically level, and did not tilt at an angle.

According to Langley the greatest weight that can be sustained by an aeroplane with one-horse power is 209lbs. ; a man can only continuously exert about one-tenth of a horse power, and the best he could do by his own effort would be to support and drive through the air a weight of 20 lbs., that is he could not possibly sustain himself in this way. Wilde has made experiments upon the discharge and reactive force of elastic fluids, which proved to him that reactive force produced in this manner cannot be utilised to produce ascending power for aerial navigation.

In *Engineering*, Vol. V., is published an exceedingly interesting communication, entitled "On the flight of birds, etc., in reference to the subject of Aerial Navigation," by M. de Lucy, of Paris. This writer, basing his arguments upon observations made upon the flight of birds and other beings which use the air as a means of locomotion, contends that weight instead of being an obstacle is actually necessary for successful flight. He states that the three fundamental conditions are weight, surface and force. The rate at which a body will fall through air will depend upon the horizontal surface which it exposes to the air in relation to its weight. As an example take a bullet and a sheet of notepaper. If the paper is held with its surface horizontal, and it is allowed to fall, the descent will be slow owing to the resistance offered by the air. The bullet, on the contrary, will fall rapidly and reach the ground in a much shorter space of time if released at the same height. But make the same sheet of paper into a compact ball, and roll the bullet out flat, so that it becomes a thin sheet of foil, and the rates of descent will be quite altered. The weight of lead will be the same as before, but in the form of a thin sheet it will travel slowly owing to resistance of the air against its surface. The weight of paper will also be the same as before, but it will travel comparatively quickly as its surface will offer very small resistance to the air. As the speed of a surface moving through air increases so does the resistance. When the direction is downwards, the result of this is that the force of gravity is being repeatedly neutralised by the upward thrust of the air against the moving surface. But the surface must continue to fall, because as its velocity decreases the thrusting effect of the air also decreases, and the downward pull, due to gravity, again predominates. The net result, however, is that the fall is opposed by the air, and its rate can be largely controlled by extending the area of surface, the effect produced by gravity is not the same as upon a body falling in a vacuum. Air resistance is in direct relation to the area of the surface bodies, and to the square of their velocity. De Lucy concludes that the secret of flight is in this principle of the air resistance increasing with the velocity until it balances the downward pull due to gravity.

He points out that all creatures which fly are heavier than the air they displace by their bulk, that is they do not depend upon the principle of buoyancy. Extended observations of winged creatures show that the area of their supporting wing surface is always in inverse ratio to the weight to be carried in air. That is, the heavier the creature the smaller is the size of its wings relatively to the weight which they are required to lift. The smaller the creature also the more powerful it relatively is; and necessarily so, as the power required to drive the wing is applied very near to the point of attachment to the body. Therefore, the wings being larger in proportion as the weight of the creature is less, it must be relatively able to exert more power in flying than a heavier creature with smaller wings in proportion to its weight. Insects are the strongest of all creatures relatively to their size. Taking a weight of one kilogramme (2·2 lbs. approx.) as a standard of reference, de Lucy finds that a gnat, for example, would require wings having an area of 11 square yds., 8 square ft., 92 square ins., to support this weight, and a bee 1 square yd., 2 square ft., 74½ square ins., only. A gnat weighs 460 times less than a stag beetle, and has fourteen times more wing surface. A sparrow weighs ten times less than a pigeon, and has twice as much wing surface. The sparrow weighs 339 times less than the Australian crane and has seven times more surface, all relatively to weight supported. This latter bird is remarkable for its excellent flying powers, taking the longest and most remote journeys of all travelling birds. With the exception of the eagle they are the birds which take the highest flights.

The shape of the wings, their texture and number, and matter of which they are composed are of secondary importance. The most important part is the extension of supporting surface. Secondly, the place of attachment of the wing point relatively to the body. Nature places this above, but close to the centre of gravity, to preserve equilibrium, notwithstanding all kinds of movement made by the bird. Gliding birds are provided with pointed or tapered wings, flapping birds have wings which are more rounded and hollow. The flying creature depends very much upon its momentum to resist the force of gravity. Without a considerable amount of weight in proportion to its size it could not make full use of this principle. Like a projectile, once it has gained a certain amount of speed, it can continue for an interval of time to proceed through the air without falling and without flapping its wings. De Lucy has discovered a law that a winged animal, weighing from eight to ten times more than another has always two times less surface. The surface required to support a man should be determined by reference to the largest and heaviest bird, say, for example, the Australian crane. De Lucy assumes this bird to develop an average power of 20 kilogrammes (about ¼ horse-power). Taking the weight of a man and flying apparatus to be 100 kilogrammes (220 lbs. approx.) the force required to enable him to fly would be, according to this reasoning, 200 kilogrammetres (about 2½ horse-power), that is following the law of decrease of force required in proportion to weights and volumes and a supporting surface of 9 square metres (10 square yds., 6 square ft., 126 square ins.). To support ten times this weight, that is to support 1,000 kilogrammes (2,200 lbs. approx.), he takes half of the surface for 100 kilogrammes as a basis, and finds that for 1,000 kilogrammes to be sustained the surface necessary is 22 square metres, 50 square centimetres (31 square yds. 2 square ft. 123½ square ins.). Following the same reasoning, the surface to support 10,000 kilogrammes (22,000 lbs. approx.) would be 112 square metres, and for 100,000 kilogrammes (220,000 lbs. approx.) 360 square metres. He believes the force required would follow the same law for the greater weights, but states, however, that experience is the great word.

De Lucy arrives at the conclusion that a flying apparatus designed to support a man and to be moved by the force of that man will always be too heavy for its volume in relation to the force necessary to propel it. Aerial navigation can and will be only successful with large machines. Weight increases by simple proportion, but surfaces and volumes as the square and cube. If a flying apparatus is made of very large size, its weight will be insignificant relatively to the volume. As an illustration, he refers to a small balloon of one metre diameter made of a certain thickness of silk and inflated with hydrogen gas cannot raise itself, but if the diameter is increased 10 times, it will not only rise, but lift 550 kilogrammes (1,210 lbs. approximately).

Others do not agree with this idea, and believe that large machines are not practicable—that because a design may work well in a small size it will not necessarily be successful when made of large size. From similar reasoning it has been argued that all flying machines will be failures from a useful point of view. Wilde somewhat agrees with the reasoning of de Lucy, as he is of opinion that aeroplanes are of the nature of projectiles, and is confident that the problem will be solved. He suggests the idea of a parachute with its action reversed by a vibrating movement as the one remaining method failing the discovery of some new property of matter.

Contemplating these various opinions and results of observations which show that the experimenters and observers have brought considerable intelligence to bear upon the subject, we may fairly conclude that aerial navigation by machines heavier than air will eventually be accomplished. Probably various types of airship or flying apparatus will remain in use, each being that suitable for some particular purpose. Balloons with yet further improvements can serve within certain limits. Apparatus to be used by individuals will be likely to follow the gliding principle as illustrated by that practised by Lilienthal, Pilcher, Chanute, and others, first as a sport and then for ordinary purposes of locomotion, again within limits. The experiments of Le Bris and Phillips, however, indicate that we do not know all that can be accomplished by utilising not only the lifting but the aspirating effects produced by air currents in contact with curved surfaces, and the limits of movement with gliding apparatus may be much wider than would seem possible at this moment. Large flying machines may utilise several methods in combination — horizontal screws to produce the preliminary elevation, fixed planes to maintain the load during flight and to assist in safe descent. The supporting power of the wind will be made use of, and the projectile principle will come into action to neutralise the effect of gravity. Weight will be incidental and not a thing to be eliminated, as far as possible, at all cost. In marine navigation we have a great range of appliances, from the canoe to the ocean liner and battleship. For land locomotion mankind makes use of many machines, each applicable to certain purposes, and all requiring skill in their use; people cannot even walk without having acquired by practice the ability to do so. To support ourselves and move in the air we must be prepared to accept similar conditions, creating appliances by degrees, one improvement following another, the skill and knowledge to use them being acquired gradually and through many failures. Just as the ability to make and manage a modern steamship has required many years of application, so will that required to make and manage the equivalent airship demand its full toll of study and sacrifice.

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